SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Federation—Past and Future—Emerson and Wolman

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FEBRUARY, 1953—VOL. 25, No. 2

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TWENTY-SIXTH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

BAYFRONT AUDITORIUM

MIAMI, FLORIDA

October 13-16, 1953

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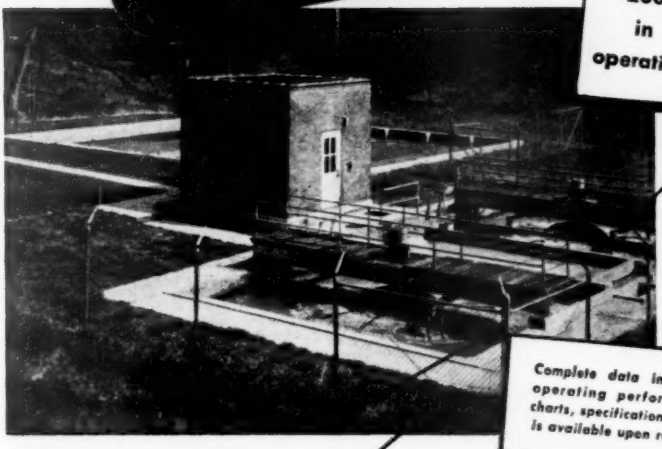

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SEWAGE AND INDUSTRIAL WASTES

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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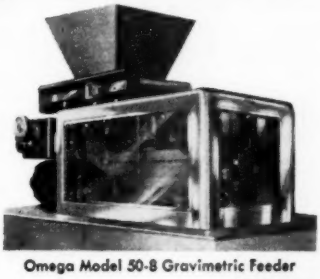

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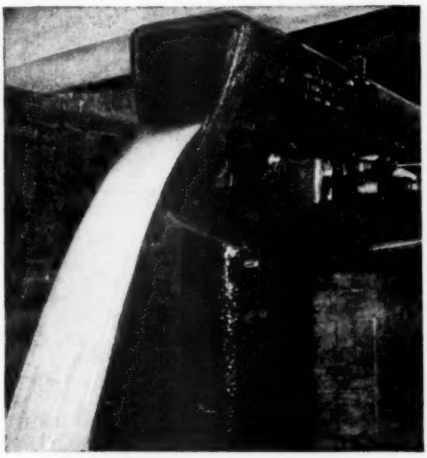

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MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Texas Water and Sewage Works Assn.	Texas A & M College, College Station, Tex.	Mar. 8–12, 1953
New Jersey Sewage and Industrial Wastes Assn.	Hotel Traymore, Atlantic City, N. J.	March 11–13, 1953
Arkansas Water and Sewage Conference	Hotel Marion, Little Rock, Ark.	Mar. 16–18, 1953
Louisiana Conference on Water Supply and Sewerage	La. State College, Baton Rouge, La.	March 18–19, 1953
South Carolina Water and Sewage Works Assn.	Clemson College, Spartansburg, S. C.	Apr. 2–4, 1953
Arizona Sewage and Water Works Assn.	San Marcos Hotel, Chandler, Ariz.	Apr. 16–18, 1953
Kansas Sewage and Industrial Wastes Association	Hotel Broadview, Wichita, Kans.	Apr. 22–24, 1953
California Sewage and Industrial Wastes Association	Mar Monte Hotel, Santa Barbara, Calif.	Apr. 22–25, 1953
Maryland-Delaware Water and Sewerage Association	Commander Hotel, Ocean City, Md.	May 20–21, 1953
Virginia Industrial Wastes and Sewage Works Association	Hotel Jefferson, Richmond, Va.	May 21–22, 1953
Central States Sewage and Industrial Wastes Assn.	Hotel Pere Marquette, Peoria, Ill.	June 3–5, 1953
Ohio Sewage and Industrial Wastes Treatment Conference	Mayflower Hotel, Akron, Ohio	June 17–19, 1953
Pennsylvania Sewage and Industrial Wastes Assn.	Pa. State College, State College, Pa.	Aug. 26–28, 1953
Iowa Sewage Works Assn.	Iowa State College, Ames, Iowa	Sept. 2–4, 1953
Rocky Mountain Sewage Works Association	Hotel La Fonda, Santa Fe, N. M.	Sept. 21, 1953
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Owensboro Hotel, Owensboro, Ky.	Sept. 21–23, 1953
Missouri Water and Sewerage Conference	Elms Hotel, Excelsior Springs, Mo.	Sept. 27–29, 1953

TWENTY-SIXTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations

in conjunction with

Florida Sewage and Industrial Wastes Association

Municipal (Bayfront Park) Auditorium, Miami, Florida

October 13–16, 1953

Address hotel reservation requests to: FSIWA Convention Housing Bureau, 320 N.E. Fifth Street, Miami, Florida

North Carolina Sewage and Industrial Waste Association	Sheraton Hotel, High Point, N. C.	Nov. 9–11, 1953
Nebraska Sewage and Industrial Wastes Association	Hotel Capitol, Lincoln, Nebr.	Nov. 12–13, 1953
Oklahoma Water, Sewage and Industrial Wastes Conference	Okla. A & M College, Stillwater, Okla.	Nov. 16–20, 1953

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Efficient treatment is the main objective, of course; but the extraordinarily low cost of Yeomans plants—as to both construction and operating costs—is a factor that is pleasant to consider.

If you have a knotty problem of industrial waste treatment, it makes much sense at absolutely no cost to find out what we may be able to contribute to solving it. Just write a letter.

A "Package" Treatment Plant for Every Small Community

Many small communities, outlying schools and housing projects face the perplexing problem of how to treat small quantities of domestic sewage on a small budget—a problem multiplying rapidly as new residential developments spring up near big cities. Usually the cost of hooking up to the city's treatment plant is prohibitive; and there just hasn't been an efficient low-cost alternative.
Now it's different—

- Yeomans has developed a series of "package plants" engineered for population groups of 50 up to 2500.

These plants are compact, simple, efficient, exceedingly economical both as to construction and operation. They require only normal "good housekeeping"—a few minutes a day of a handy-man's time. The plant may be of biological trickling filter or activated sludge type—whatever community needs dictate.

A bulletin now in preparation will be found most valuable. Glad to reserve a copy—write.

The Yeomans Guard, published several times a year, is a compendium of news and useful information concerning the pumping of materials and the treatment of wastes, both domestic and industrial. We shall be pleased to send you the current issue—ask your local Yeomans representative listed in the Classified Directory under "Pumps", or write us.

90% B.O.D. Removal in "Aero-Filter" Plant at Plant City, Fla.

How's this for a letter?

"The Florida State Board of Health joins the City of Plant City in its pride in having such an excellent sewage treatment plant." The letter to T. J. McCall, City Manager, continues "and certainly Plant City has set an example which would be very profitable for other cities to follow."

In a later letter the State Board of Health added, ". . . we now have almost a year's operating data on this plant and . . . apparently it is achieving a B.O.D. removal in excess of 90 per cent."

This all-Yeomans waste treatment plant, built around an "Aero-Filter" and four dual Streamline Sludge Collectors, was designed by Alan B. Pimm, Consulting Engineer of Tampa, Fla., to meet the needs of the present population of approximately 10,000 with provision for possible future population growth to 15,000.

The happy sequel to this success story is the fact that numerous other communities *are* following Plant City's example. They're specifying Yeomans treatment equipment and getting high efficiency at low cost.

Sealed for 20 Years— Still Going Strong

. . . Among many intriguing stories about Shone® Ejector performance, there's one we especially like:

A Shone installed in one of Chicago's best known buildings was inadvertently sealed off during alterations; and because it had not been listed in the mechanical equipment inventory, it was not missed. Twenty years later, when further alterations broke into its concrete tomb, there was the doughty Shone, pumping away as rhythmically as the day it was installed. The faithful Shone!

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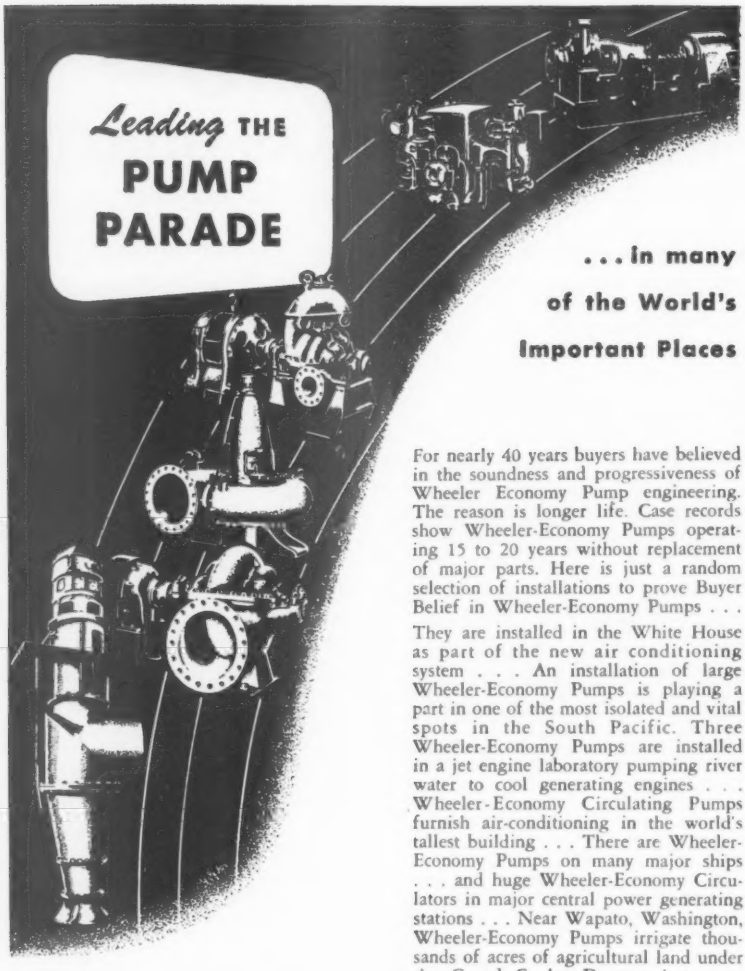

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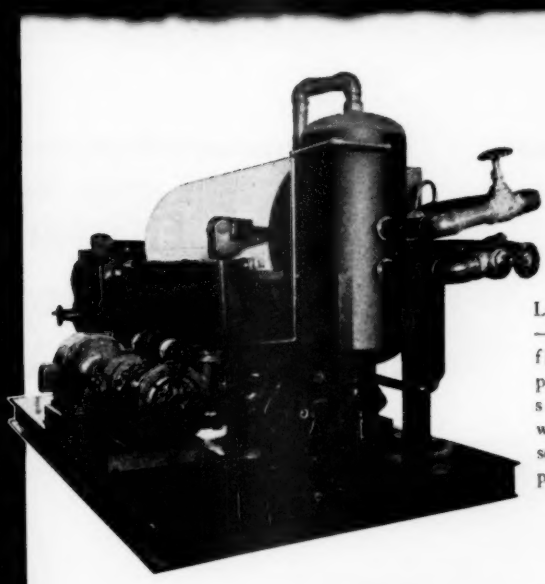

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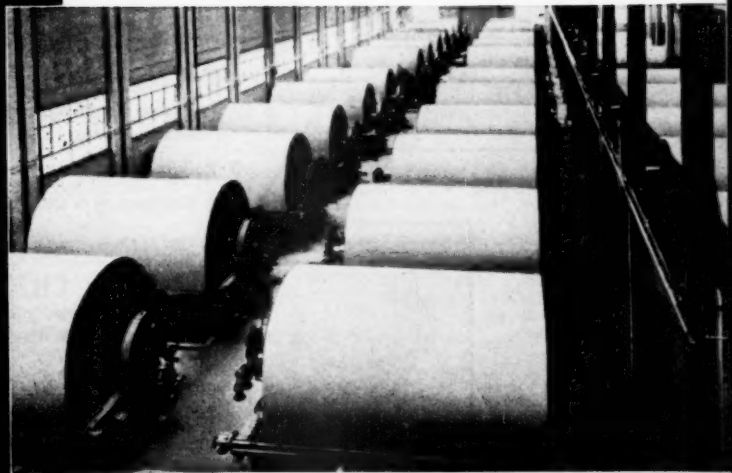

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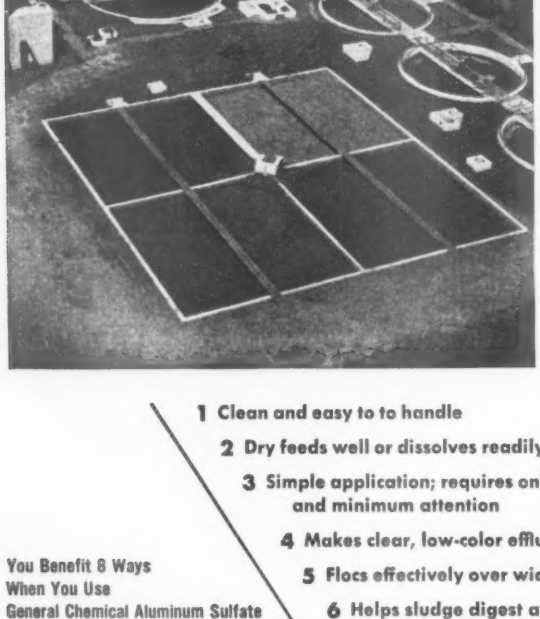

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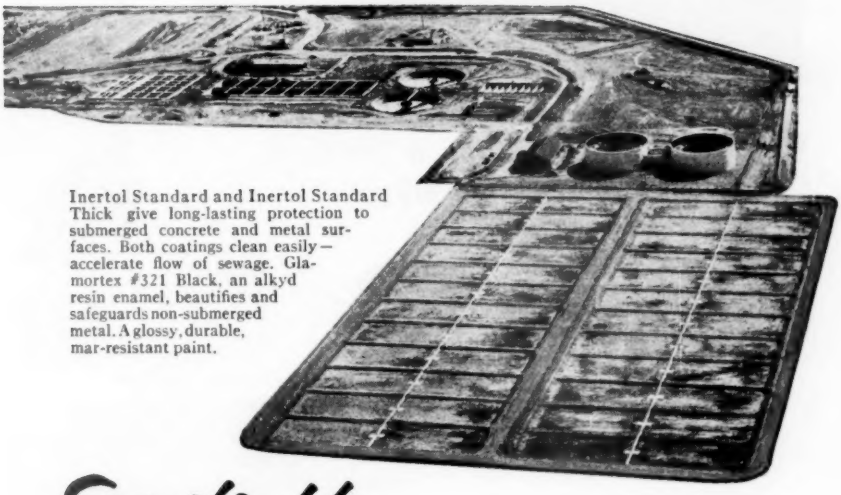

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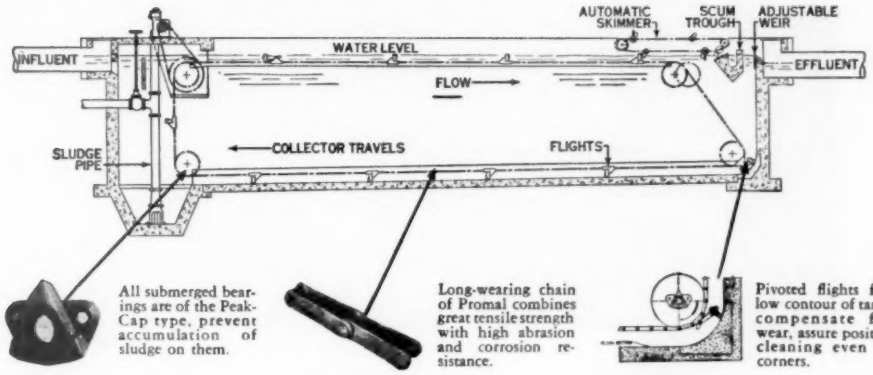
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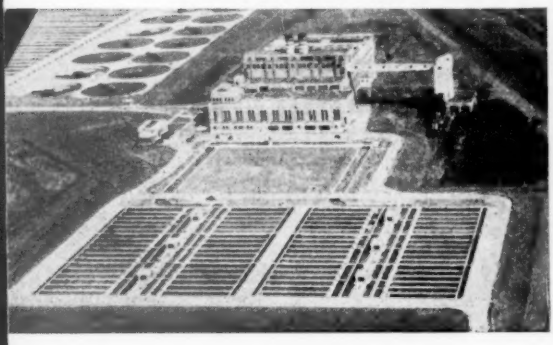

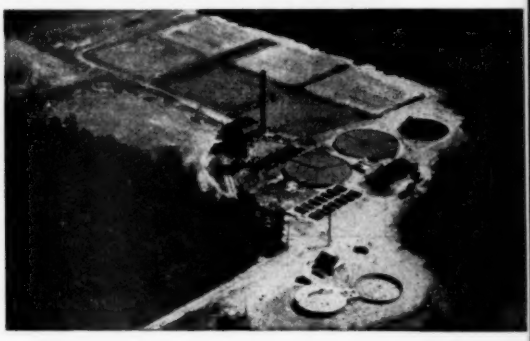

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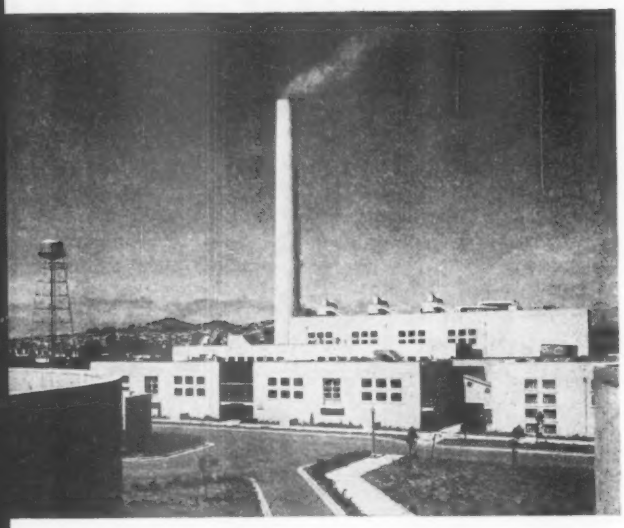

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4 — Coarse bar screens, 3" openings.
4 — Fine bar screens, 1" openings.
4 — Belt feeders to grinders.
4 — Screenings grinders, 2000# per hour each.
4 — Grit channels, each equipped with two scraper collectors and one V-bucket elevator.
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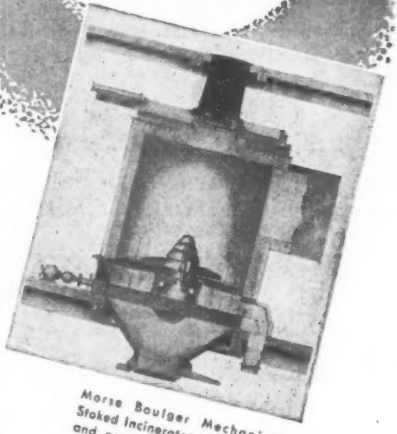

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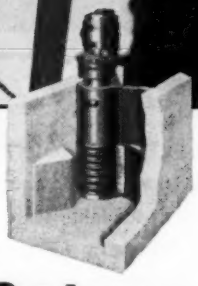

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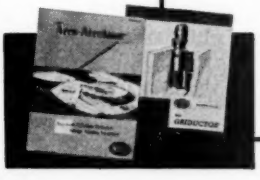

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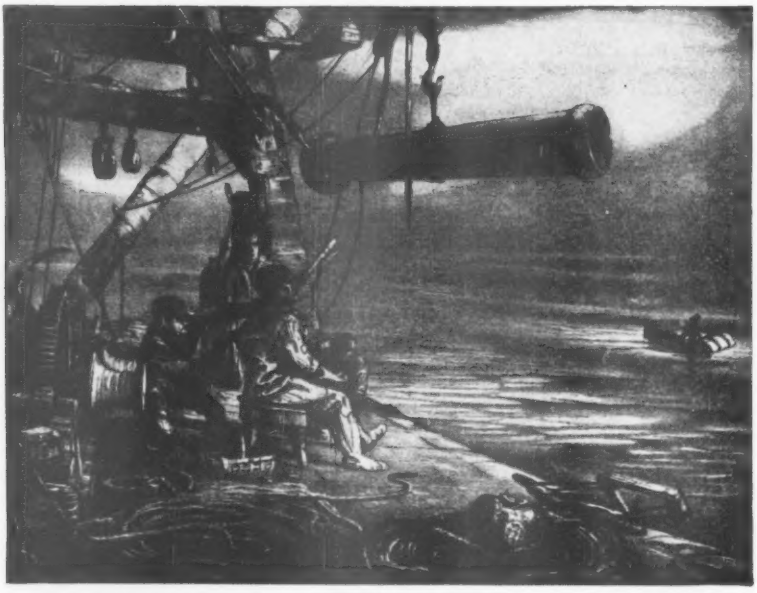

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 25 **February, 1953** **Number 2**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

Herbert P. Orland, *Associate Editor* Dr. F. W. Mohlman, *Advisory Editor*

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Repair Cost *per unit*	$ 53.05
Repair Cost, per unit, *per year*	$ 4.08
% of Original Cost spent for all repairs in 13 years	0.6%

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Sewage Works

THE FEDERATION—PAST AND FUTURE*

I. A Quarter Century of Progress

By Charles A. Emerson

Consulting Engineer, Havens and Emerson, New York, N. Y., and original Chairman, FSIWA

For many, the birth of the Federation antedates their activity in the field of sewage treatment. But to the oldsters, and particularly the venerable members of the Quarter Century Operators' Club and members of the first Board of Control sitting alongside me, it merely means looking back along the road a way to a time when it was easier to sit up late at night, with a group of congenial spirits gathered about a table, in discussion of methods for curing foaming in Imhoff tanks, or whether the best tomatoes could be raised in the glass-covered sludge bed or out of doors, or some other equally scientific problem.

In some ways those were the good old days, for unless sewage pumping was involved there were few electric motors and no solenoids or similar delicate gadgets. Detergents were unknown and the public wasn't so pollution conscious that an occasional "pulling of the plug" for a few hours during repairs was certain to cause headlines in the local paper. However, plenty of hard work was involved, which, if many of us had to do it today, would make rheumatic backs or arthritic joints creak.

Some State Associations in Existence

At the inception of the Federation, conditions weren't as bad as many might suppose. It wasn't necessary to follow a dim path through the weeds to find the sewage treatment plant. There were many well-designed plants in operation throughout the East, the South, and the Midwest, and most of the larger ones had reasonably adequate staffs under leadership of technically trained superintendents. Many state health departments had sanitary engineering divisions. Research work was underway at New Brunswick, N. J.; Champaign and Chicago, Ill.; Ames, Iowa; Boston and Lawrence, Mass.; and other places. Sewage Works Associations were in existence in New Jersey, Texas, North Carolina, Pennsylvania, Missouri, Kansas, and Iowa. Numerous articles on sewage treatment were appearing in various technical journals.

But, unfortunately, there was no coordinated effort and all of these agencies were struggling along independently. Membership in State Associations was limited and frequently funds were not available for publication of papers. Research men complained that editors "blue pencilled" articles so heavily that much of their value was lost. The great rank and file of operators of the smaller plants were without adequate instruction and there were no ready means whereby they could secure information in an understandable and practical form to help in solving troublesome operating problems. The situation was of great concern, but no solution was in sight.

* Two addresses presented at the Silver Anniversary Luncheon, Federation of Sewage and Industrial Wastes Associations; New York, N. Y.; October 6–9, 1952.

Fundamentals of Federation Founding

Finally, at a meeting of the Association of State Sanitary Engineers in Buffalo, N. Y., on October 14, 1926, it was decided to invite some interested outsiders to sit in on a general discussion. George W. Fuller, Dr. Willem Rudolfs, Arthur Bedell, and I were among the guests. Dr. Rudolfs made a plea for a better medium for publication of research papers. Others also spoke, but nothing tangible was accomplished. Throughout the meeting, George W. Fuller sat quietly smoking his pipe, but made no comments. However, at dinner at the hotel that evening, he said: "I think I've got the answer and will tell you about it in a couple of days."

Shortly thereafter, Kenneth Allen, William J. Orchard, and I were called to his office. It was then and there that the Federation was conceived by keen-thinking, practical-minded George W. Fuller.

His thoughts were:

1. A national sewage association with an annual meeting was out of the question at the start, because few operators could obtain authorization to attend a convention which might be several hundred miles distant.

2. Desired results could be obtained by strengthening existing state sewage works associations and formation of others. He felt that municipal officials would be inclined to authorize expenses for a trip by the operator to a meeting within his own state, particularly if requested to do so by their own State Department of Health.

3. The local associations should be joined into a country-wide Federation, to be guided by representatives selected by each of the member groups to act as a Board of Control.

4. A journal should be published and distributed to every member of the local associations at a moderate price.

Although the idea at once appealed to all of us, we were told to think it over and talk it over with friends and come back for another meeting in a week.

George W. Fuller

I wish all of you could have known George Fuller and Kenneth Allen as was my privilege, for I am sure you would treasure memories of them throughout your life.

Fuller was a hard worker and a hard player. Notwithstanding a busy life in active practice as one of the outstanding consulting engineers, he gave freely of his time to the upbuilding of his profession and to furthering the interests of its younger members. His qualities of understanding, kindliness, tact, and common sense were conspicuous. I well remember how he occasionally remarked that, "In a complicated problem you can get 90 per cent of the truth in 10 per cent of the time, but you've got to determine whether you are justified in spending 90 per cent of the time to gather that last 10 per cent of the truth."

Another incident comes to mind which is applicable to any who may have a youngster about to enter college. We were on a water job in the Midwest and the manager of the water company had a boy who had a fine athletic record in high school and was being solicited by several colleges; but, unfortunately, not by the school his dad wanted him to attend. So, thinking to get some inside dope, he staged an elaborate lunch at the Athletic Club for Fuller. I was fortunate enough to get in on the feed. At dessert he said: "Mr. Fuller, I understand there are six boys in your family and that they all have attended different schools and taken different courses. How did you arrange it?" Fuller quietly smiled and said, "I did pretty well and only made one mistake. I wanted to make a sanitary engineer out of my oldest boy and tried to tell

him what school to attend. He flunked out, but graduated with honors from another school he selected for himself."

Kenneth Allen

Kenneth Allen possessed a kindly and amiable disposition, which never seemed to become ruffled by occurrences such as frequently upset most of us. He was devoted to his profession and always interested in helping its younger members. In his service of about 10 years for the City of New York in studies of harbor phenomena, he had much to do with shaping the general plan which the City is now following in its great sewage treatment program. The New York State Sewage and Industrial Wastes Association does well to use his name to designate its principal award.

Original Financing

But to get back to 1926—it developed at the following meeting one week later that Bill Orchard, with characteristic enthusiasm, had secured definite promises from 20 firms to take advertising space for one year in a sewerage journal. The contemplated advertising revenue, together with an estimated initial membership of 500 at $1.00 per year each, would make a total income of $7,200, or about enough for printing and distributing four issues of a journal of 100 pages each.

Having this assurance of ability to finance a journal, the next step was to ascertain the probable support to be expected from health officials, consulting engineers, existing sewage works associations, and that most important group, the operators. Letters to key men brought enthusiastic replies: informal group meetings in Detroit, Cincinnati, and St. Louis also elicited many promises of support.

Formation of Committee of 100

Every indication was favorable, and it was decided to go ahead. Accordingly, Harrison P. Eddy sent letters to a selected group of sanitarians suggesting a dinner meeting in Chicago, on June 10, 1927, for discussion and formulation of plans to be presented at a general meeting to be held the following morning on adjournment of the A.W.W.A. Convention.

At that meeting, on motion of George W. Fuller, the famous Committee of One Hundred was authorized for the purpose of coordinating the efforts of interested groups and making definite recommendations for procedure. The Committee was appointed on July 15, 1927, and rendered its final report at a meeting in Cincinnati on October 21. This report fully endorsed the Federation idea, indicated that research papers and operating data on plant costs and efficiency were available or in prospect to the extent of some 300 printed pages a year for the next few years, and that prospective advertising revenue and modest dues from members would be sufficient for printing and distribution costs. Then came a new and smaller committee, which reported a definite program at a meeting in New York City on January 19, 1928, and in turn became an Implementing Committee appointed on March 8 and based on four sub-committees, as follows:

Organization Committee: Harold W. Streeter, Chr.
Finance Committee: Wm. J. Orchard, Chr.
Publication Committee: John R. Downes, Chr.
Coordination Committee: Kenneth Allen, Chr.

A name was selected for the Federation and for the *Journal* and all the Committees were put to work. Dr. F. W. Mohlman was selected as Editor at a meeting of the Publication Committee in Trenton, N. J., on March 28 and in July, Howard E. Moses was appointed Secretary-Treasurer.

Entry of Chemical Foundation

A milestone which loomed on the horizon at this time was entry of Chemical Foundation into the picture. Chemical Foundation was a quasi-governmental agency formed during World War I to administer certain patents and processes seized by the Alien Enemy Property Custodian and to dispense the proceeds for furthering progress in science. The impounded royalties on the United States patent granted Karl Imhoff constituted some of this income and could be devoted to sanitation. Fortunately, Dr. Rudolfs was acquainted with W. W. Buffum, General Manager of the Foundation, and at a meeting of the American Chemical Society in St. Louis introduced him to a group of some five or six sanitarians gathered for luncheon and steered the talk around to a discussion of the proposed Federation. Buffum became interested, and following his return to New York there were several meetings between Francis Garvin, President of the Foundation, and the Federation's New York group. These resulted in a letter from Buffum on May 11, 1928, with the decision that remaining funds available for sewage research could be spent to better advantage in furthering the Federation than in continuing with grants to individuals to finance specific research projects, as had been the Foundation's custom. Accordingly, they offered to take over the entire business management of the *Journal* for a trial period of a year, underwrite any deficit, and turn over any profit. This added backing clinched our financial position and was promptly accepted. The arrangement with Chemical Foundation continued full-scale for more than 11 years, until Mr. Buffum's death in 1940.

Although the Federation probably could have existed without the backing of Chemical Foundation, it is certain that the approximately $6,750 cash they contributed, plus the efficient and painstaking efforts of their staff in management of the *Journal*, contributed greatly to the rapid growth of the Federation in its earlier years.

First Board of Control Meeting

Everything now seemed ready for the launching. Accordingly, an organization meeting of the Board of Control was held in the Stevens Hotel, Chicago, on October 16, 1928, and was attended by 11 representatives of eight associations, which at their local meetings had voted to affiliate and had elected representatives. These eight charter Member Associations were Arizona, California, Central States, Iowa, Maryland, North Carolina, Pennsylvania, and Texas.

First Officers

At this meeting, a Constitution and By-Laws were adopted, officers were elected, committees were appointed, and the ship started down the harbor to the open sea.

Officers elected at the meeting were:

Chairman: C. A. Emerson
Vice-Chairman: Abel Wolman
Secretary-Treasurer: H. E. Moses
Business Manager: W. W. Buffum
Editor: F. W. Mohlman

Growth of Journal

The first number of *Sewage Works Journal* appeared late in October, 1928, and was sent to 273 subscribers.

From the start there had always been more than sufficient excellent material pressing for publication, with result that the volume for 1931 contained 793 pages of editorial matter, or almost double the number initially contemplated. It was then decided to issue the *Journal* bi-monthly, instead of quarterly, but without increase in dues. This was an unusual step in the midst of the "Great Depression," but as there was about $2,000 in the treasury, the chance was taken.

In 1937, the development of Federation activities and rising costs in publication necessitated increase in subscription price to $1.50. Since then

the continued rise in printing costs and in volume of editorial matter necessitated further increases to the present price of $5.00 for Active Members, as instituted in January, 1950, when the *Journal* became a monthly publication. The Federation has never made any money on the Active Member subscription price for the *Journal*. From the very start the actual cost of printing and mailing, exclusive of editorial and overhead expenses, has equalled or exceeded the subscription price.

The *Journal* has kept fully abreast of developments in the art of sewage treatment. Its outstanding success in the United States and abroad has, of course, been due in major part to the untiring efforts of Dr. Mohlman, who bore the burden of editorship for 13 years and continues to this day as Advisory Editor.

First Decade

When the Federation was organized it was hoped to attain a membership of 1,000 in 10 years, but at the conclusion of the decade there was a net membership of 2,472 here and abroad, with 399 non-member subscribers to the *Journal*, or nearly three times our rosiest expectations. The tenth anniversary was celebrated by publication of the 371-page volume entitled "Modern Sewage Disposal," which was produced through the untiring editorial efforts of that loyal member of the Central States Association, Langdon Pearse. Some 2,500 copies were sold, netting a welcome profit to the Federation.

Permanent Secretariat Established

The continued growth and increasing usefulness of the Federation during the first decade made it evident that the original type of organization, largely managed by part-time efforts of volunteer officers, could not hope to adequately meet the multitudinous needs of the workers in the rapidly growing and ever changing sewage works field. Accordingly, a Special Committee was appointed and at the Annual Meeting on January 18, 1940, recommended a long-term program, which has since been adopted in full.

The initial step was decision to inaugurate annual conventions. Those who were present at the Hotel Sherman in Chicago in October, 1940, recall that attendance exceeded 600, that the 55 exhibitors were well pleased, and that the Convention was a success technically, socially, and financially. Then three months later, on January 15, 1941, at a special meeting of the Board of Control, authorization was given for establishment of an Executive Secretary's office with W. H. Wisely to serve as Secretary on a half-time basis at the start and for perfection of closer cooperation with the Water and Sewage Works Manufacturers' Association.

At this meeting the yeoman work of Howard E. Moses, who had served as Secretary since inception of the Federation, was recognized by his designation as Honorary Secretary.

1940 marked the start of activities of the Sewage Works Practice Committee, which to date under Morris M. Cohn has produced five valuable Manuals of Practice and has several others in course of production. It also saw Frank Woodbury Jones and the eight charter members of the Quarter Century Operators' Club seated in glory. Now this group numbers more than 35. All are zealous of their membership, and properly so.

Manufacturers' Activities

We all profit in study of the exhibits by member firms of the Water and Sewage Works Manufacturers' Association. Many of us likewise enjoy the evening calls on manufacturers' representatives, which give opportunity to answer the currently important television and radio question: "What'll you have?"

The liberal grants by the manufacturers' group have meant much to the Federation throughout the years, and I am proud to record that there are

absolutely no strings attached to them. Their three representatives on the Board of Control constitute less than 6 per cent of its total membership. Never once have they considered a question from the standpoint of benefit to the manufacturers as opposed to furtherance of the general interests of the Federation.

The support of the *Journal* by its advertisers has been most gratifying from the start. It is noteworthy that five firms who had full-page advertisements in the first issue of *Sewage Works Journal* have continued to take the same space in every issue since that time. These firms are The Cast Iron Pipe Research Association, Dorr Company, Link-Belt Company, Pacific Flush Tank Company, and Wallace and Tiernan. More power to them, and may the 37 other firms that have advertisements in the current issue follow their example and continue with us for the next 25 years!

Current Status

Well, here we are, sitting on top of the world, participating in a top-notch national convention of an established organization with 37 Member Associations here and abroad, an efficient central office, a monthly *Journal*, a healthy surplus, and—best of all—more than 5,500 Active Members. I think we got up here by pulling on our own boot straps, but be that as it may, it is certain that past achievements must be considered merely as incentives to increase the strength and usefulness of the Federation.

II. Responsibilities and Problems of the Future

By Abel Wolman

Professor of Sanitary Engineering, The Johns Hopkins University, Baltimore, Md., and original Vice-Chairman, FSIWA

When asked to undertake the task of crystal-ball-gazing it must be confessed that I looked upon it with considerable of a jaundiced eye. The assignment was accepted primarily because there is one virtue in prophecy, and there is one prerogative which the prophet has. He can say a great many things—some of which may be foolish, some of which may be imaginative, and some of which may in time turn out to be accurate. But regardless of how foolish some of the comments may be, he can make them under the cloak of prophecy. And if they turn out to be wrong, or if they turn out to be foolish, criticism cannot be too heavily heaped upon him.

I took refuge, therefore, in that opportunity and what I have to say centers on the Federation and its future, particularly after what Mr. Emerson has related about the past. I tried to see in what direction, to what degree, and in what areas the Federation might move in the next 25 years. This did not turn out to be such a difficult task. It has already been indicated that one of the major topics 25 years from now will be foaming and frothing, because, as most of us realize who look at the past and try to build the future on it, in the past lies a great deal of the prediction as to the future.

George Sarton, the famous historian of science, has pointed out that in science the future always starts in the past. He says that each man adds his stone to this edifice, and sometimes—and this is important—an old building is broken down into pieces and then the old stones are used again in a new configuration to build a new and different edifice. And as we look back over

the field of sanitation and of sewage and water treatment we find this is literally as well as figuratively true. Although the stones are rearranged, they are built into structures to fit as if they are new, and actually new stones are sometimes added to the edifice.

As I proceed you will recognize in some of the future a good deal of the past. You will recognize, it is hoped, that some of the old edifices need to be destroyed—a task, incidentally, which is not made too simple, because an old edifice not only has permanence, it has familiarity. And the deviation from the familiar for the future is always a hazard.

Fate of Future Rests on Younger Group

As I look around this room and see those who are not yet so gray, the fate of the future rests with them. They will look at some of these old structures and say: "They may have served their time and they may have served their purpose, but let us begin to tear them down, rearrange the bricks, make a new adjustment in them, and see where it may lead."

This is obviously not the time to discuss the major anticipated changes in technology, although I cannot resist listing some of them, because the Federation in the past and the Federation in the future is going to have a great deal to do and say about crystallizing and formalizing technological principles. It has the duty and the obligation to perform this task with the greatest wisdom.

Technological Problems

What are some of those technological problems? What are some of the old edifices that need to be redesigned? I run through them rapidly because it is the cautious thing to do.

Those technological problems all have familiar names. Virtually everyone can conjure up reasons why some of the stones need to be rearranged; why some pieces of the buildings ought to be adjusted.

Settling

Settling—a simple term and an orthodox one. Aside from the fact that settling periods find their way into most regulations and become so crystallized that they are almost acts of God, why are the periods of settling as now accepted in many state board of health regulations, and in textbooks, 10 or 20 or 30 years behind the times? What is there so mystical in a 3-hr. settling period? But by now it has almost the fiat of the laws of the Medes and Persians. Some venturesome individual recently suggested that plain preliminary settling, in some instances, in some places, might profitably be reduced to 30 min. I do not know whether he has been shot yet at dawn, but if he's heroic, and if he's energetic, and if he likewise has a few friends in the profession, he may be permitted to build such a tank somewhere, if only to prove either the validity of what he said or the foolishness of what he did. This is one edifice that needs to be looked at again.

Filtration

When we come to filtration we are equally hide-bound. Almost every text gives the number of pounds of B.O.D. per cubic foot of something that cannot be exceeded. And depending on the temperament and the attitude of the writer, it can be exceeded by 0.1 but not by 10 per cent. How does it come about that a situation remains as static as this? Are there no hopes in high-rate filtration *per se*; in a better total use of the stone; in a better general distribution horizontally as well as vertically?

Are there no hopes in mechanical filtration or in micro-straining? It is a source of some professional chagrin that much of the development in mechanical filtration to date comes from abroad. It is an extraordinary sensa-

tion for an observer, in England, in pre-war Germany, in Holland, or in some of the Scandinavian countries, to find ourselves being dignified as the country of conservatism, where the new idea, where the deviation from the orthodox, is suspect. It may be part of the national climate of orthodox opinion to which I want to return later on.

Activated Sludge

Even in the activated sludge process we do toy with various places and ways of introducing the air, but we do not do much more than toy with it. Our fundamental understanding of that process is not much better than it was at the beginning of the Federation. What can the Federation do to stimulate basic investigation rather than putting the point of entry of air at one place or another and praying, of course, that the idea is good? Is the shallow tank of Holland being neglected? What is the hope for catalysts in the process?

Sludge

The perennial problem of sludge still overwhelms the profession. It is true we have done more than toy with it, because you do not toy with sludge! It is almost axiomatic that what we do is cart it around from place to place. Perhaps one of the best nonprofessional descriptions of sludge has been given already in the decadent song called "The Thing." In case you have forgotten, "The Thing" was handed from one person to the other and nobody wanted to have anything to do with it. And although there have been, of course, tremendous improvements mechanically, electrically, osmotically, and so on, in the handling of sludge, the problem is still with us. What can the Federation do to recapture an enthusiasm in that field which will disclose a better, cheaper, more satisfactory answer, perhaps even one of total conservation? Have we exhausted the field of composting? Are any of the new solvents applicable? There are some signs on the horizon.

Garbage

We have a parallel in the field of garbage. People could never quite understand how a reasonably respectable person could get so tied up with such a disreputable material. But wherever there is community living, where there are aggregates of population, there you have garbage. For many years the Federation papers were filled with the plea that garbage should never muddy up the waters of sewage; that we already had loads of trouble without it; therefore let us leave that other peck of trouble to another set of peculiar practitioners who cannot avoid getting involved with it. The public will remind us again and again that this municipal residue, as well as sewage—the other municipal residue—is part of our problem and responsibility.

Sewage Re-Use

We very carefully produce the finest water supplies we can in most American communities. We equally carefully see to it by the most modern developments that we then sully it by the water carriage system—one of the great sanitary advances of the last century. We then attempt, at costs that are not excessive, to get rid of the material. I have seen instances where the outfall sewer goes right by the industrial or irrigation areas where everybody thirsts for water. This liquid, which can be converted and re-used, moves by to be disposed of as rapidly as possible at some subsequent point. This is one of the edifices that needs to be torn down and rearranged, because it will become too pretentious and costly to perpetuate.

Industrial Wastes

In the problem of industrial wastes, we have perhaps one of the most fascinating areas for study and leadership ever offered to a scientific association. If ever there was a multiple set of

challenges to research, to technological process, to economics, and to political statesmanship it is in this remarkable era of industrial evolution and advancement. The pace of cooperation with industry needs to be quickened, judgment in diagnosis and control needs to be matured, and propaganda needs to be replaced by objective analysis and simplification in administrative practices of regulatory agencies. In all of these transitions the Federation should establish clear guidance.

River Behavior

In river behavior the Federation has a further challenge. Such behavior is not yet by any means completely understood. A great many people have spent a lifetime on it and are continuing to spend vigorous periods of investigation in the field to find out what it does. If there is one thing apparent, it is that no one stream ever behaves the same as any other. The variables are as many as the constants.

Administration

Perhaps the important obligation of the Federation is in the field of administration, design, and finance, where many historical structures, if not most, need to be destroyed. I come first to standards—the beloved shelter of the lazy mind, where all answers appear in handbooks, again handed down by accepted individuals, including many of us here. When the Federation gets out a handbook of practice, I always pray, and sometimes successfully, that its language will be so flexible that it cannot be quoted against the Federation later as the art and the science change.

The struggle—and this, incidentally, is a struggle which is universal and not restricted to the field of sewage treatment and stream behavior—the struggle between logic and uniformity is peculiarly important to the future in the sanitary field. The tremendous attraction of uniformity is one of the most impressive characteristics of the political and social world today. Under its influence, all things should be handled uniformly; all decisions should be across the board; regardless of geography, regardless of cost, regardless of river use, regardless of estuarial behavior, uniformity is the part of wisdom. I call it the refuge of the lazy mind because it saves all trouble. Answers are simple, even if wrong.

Recently the incoming President of the American Economic Association made an astute remark after some 30 years of exposure to economics. Dr. Williams said that "the most dangerous policy-maker is the man who knows the answer, because it fits his particular theory." This is just as applicable in the general field of sanitation.

The United States and other countries are dotted with the results of policy-making on the part of the benevolent omniscient. The omniscient policy, which covers all cases, is one of the plagues of increasingly complex adminstrative practice. It is appropriate as a Federation obligation, perhaps, to suggest to the administrator that there are occasions when he should use his head! I suspect that the bulk of the decisions which confront every man in this room, whether in practice, or in regulatory or operating position, requires an adaptation of a principle to the local problem, not to a particular red, black, or green handbook.

Financial Re-Assessment

New edifices grow: they grow out of old stones, but they will have new configurations. They add another obligation, and that is the obligation of evaluating cost. I had not intended to say anything whatever about money, but cost and money are an obligation of the Federation in the design, the construction, and the operation of works. Again as a reflection of the current climate of opinion, sometimes that feature of dollars takes second or even third place, and we hope that somewhere along the line the money will be found.

Most of the people in the Federa-

tion's field of endeavor are familiar with the term "ecology." We use it in streams and the like. It is suggested to the Federation that that terminology be extended to the total field of sewage and sewage treatment. And that the field be viewed in terms of the ecology of this society for which we are working. Considerations other than technical, other than financial, come into play in municipality, county, or sanitary district. It is the totality of necessity of the area or the municipality, that somehow or other we must include in our deliberation and in our evaluation.

Design

Now for a word about design. Are we in the era where it is possible to simplify sewage treatment plant design, not only in its processes, but also in the structures which we use to carry them out? Can something be done by that route to reduce cost? Is there such a thing as over-design? By over-design I mean are you looking at 1990 when building in 1955? There are all kinds of devices today by which terminology is used to conceal the fact that we are loading the present generation with the obligations of the distant future. Is that sound? Is it wise? Are the Federation's committees concerned with it? Is there an excessive present design?

Again people remind me that in administrative action there is such a thing as "playing it safe." What they mean is that it gets the bond issue money while the getting is good. That is an old axiom we have used ourselves, and let the chips fall where they may. Do we have the right to load the present design for the present payer? I mention in this connection that conservation does not consist of the non-use of a resource. It has been said that rivers should not be used too much for dilution, but in most respectable diagnoses and measurements, it is a sound practicable use, not only physically, but from the standpoint of conservation. Much of these basic considerations needs to be recaptured on the part of the Federation in its official thinking.

Middle Course Desirable

Lastly, may I say that the Federation might in my crystal-ball-gazing perform one of its most useful services to society as well as to the profession by attempting to traverse a middle ground between the perfectionist and the opportunist. Again I am not calling names; I am merely using descriptions of two groups of people. A middle ground between them is desirable.

As I look at those men who are less than 40 years of age, I realize that the Federation must look to that young group for the introduction once more of a high ingredient of skepticism as to what we do. Are we justifying what we pay for and are the results obtained convincing to the minds of the average citizen?

One thing can be safely predicted for the next 25 years and that is a new generation! May it be curious, inquiring, and not too respectful, so that it may preserve the sound and discard the foolish, no matter how orthodox the latter may be.

SEWAGE WORKS MANAGEMENT *

By Henry J. Graeser

Assistant Superintendent, Water Department, Dallas, Tex.

Practically every city has experienced abnormal growth since the end of World War II, which only added to the problem occasioned by growth during the war period. Most began the postwar period with a backlog of planned and deferred construction, and necessity for expanding the utility organization.

Fast growth brings management problems, as well as technical problems, to any utility or business. But in the sewage works field, management probably has had its energies devoted more to appeasing state health departments and meeting the demands of the developers than to improving the techniques of management and administration.

As the needs have grown bigger, there has been awakened a realization that the handling of people and the establishment of efficient procedure is one of the biggest technical jobs facing sewage works administrators. The best plans and plants will not alone perform their intended function if the people who manage and operate them are not organized, trained, and supervised to the maximum. Management calls for planning, organization, and direction through command. Command has been defined as: "To set going the services defined by planning and established by organization. The work program, the work order, and rules and regulations are the principal tools of command."

Sewage Works a Utility

Management is the administrator's job, and no other field is known where management and all of its implications need to be more carefully studied than in the case of sewage works utilities, which are so often parceled out between other functions and not treated as an entity—a utility.

The word "utility" is used and repeated to emphasize a point. In its growth from a small branch of a municipal government, often under the public works director, the function of collection and treatment of sanitary sewage often has evolved into an overgrown giant still laboring under the title of a minor governmental function whose policies and rates can best be determined by what is left over from the general tax fund after other more pleasant and visible activities have been cared for. Primarily, there is a great need to emphasize that this service is the equivalent of other major utilities in the city, and is a utility. It is selling a service and it deserves to be managed and operated as a utility. The service offered is on a use basis, although admittedly the proportionate use is most difficult to obtain. Basically, however, the service needs income based on use, which will allow it to meet its capital cost, maintenance and operation requirements, and to employ technical and supervisory personnel equivalent in ability to other utilities comparable in capital investment and technical requirements.

Financing expansion and providing funds with which to operate are of extreme importance to administrators of sewer systems. If they do not interest themselves in these things, the effectiveness with which they can attend to the purely technical aspects of their work will be correspondingly reduced.

* Presented at 25th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; New York, N. Y.; Oct. 6–9, 1952.

But to obtain the financial support required they must first shake themselves from the engrossing technical aspects of their profession and work on a broader plane. They must realize that they have primarily a business utility, although publicly owned, with technical phases of operation and of management. They need improved personnel practices; they need public relations advice to assure the public that the service being rendered is vital and a good buy for the money.

Certainly sewage treatment work has been obtaining increasing public acceptance as an important utility in the community. Stream pollution has rightly been widely publicized, and recognition has been gained of the extreme importance of wastes treatment work. But is enough being done? And has the importance of this group of workers exceeded its selling? It's a long, slow process to implement one's ideas of how this big business should be run and often the ideas on organization have not met with immediate acceptance. Nevertheless, there must be a tenacious, yet diplomatic dedication to this cause.

Mental Attitude Important

It is not inferred that inclusion of the Sewerage Department under the Public Works Department is necessarily wrong. Often this is the only department where an engineering staff is maintained. Also, especially in smaller cities, centralization of activities to utilize available technical personnel is a must. It is of major importance, however, that whoever directs the activities of the Sewerage Department must be utility-minded and not think of sewage collection and disposal as being just another responsibility of government. In Dallas, the Sewerage Department does not function as a separate department, but operates under a Water and Sewerage Department on an equal status with the Water Department.

Advantages of Common Administration

This has resulted from the finding that the water and sewerage utilities have common problems, which under unified commands results in considerable savings in technical and overhead personnel, materials, and equipment. Working together, but with the entity of each utility preserved by specialized direction under the superintendent, both have profited equally in rate adjustments, improvements, and operational standards. The first saving, of course, becomes apparent in the department head. By combining these two utility functions common to almost every municipality, one administrative head can be employed with broader training, and at a higher salary, than could be justified by two separate departments. Most important, however, is the fact that this administrator will think and plan on a utility basis.

This is also true in the engineering division, where close coordination of design can be obtained and the technical aspects of each construction program mastered by men with basic engineering training. Some engineers have preferences, but in Dallas all new personnel are brought up through the ranks of both phases of the work so that they can be used interchangeably in design of water systems and sewer systems. Design of plants and equipment demands special knowledge, but here again the engineering personnel double up quite readily. New connections to the system likewise can be handled quickly in one permit section, where maps of both utilities are available.

Obviously, accounting and billing can be easily combined. Of course, it is the general policy that the sewer charges are included on water bills and this probably offers no great saving. The fact that Dallas uses water consumption as a base for a sewer rate works quite well though.

Billing Procedures

There are three rates in the Dallas Water Department—water only, sewage only, and water and sewage combined. The bill for combined water and sewage services shows a total amount for water service which actually includes an increment for support of the sewage system. This may not be at all popular in many municipalities, but the citizens of Dallas prefer to have the service charge for these utilities as a "package."

Through newspaper publicity and published rate ordinances, citizens are generally aware that the water bill they pay each month also supports the sewage system. One question, of course, comes to mind; that is, water used for lawn sprinkling, which does not go into the sewer.

This problem has been solved, it is felt, quite fairly and to the satisfaction of most citizens, by offering a summer rate for the months of June through September each year. During this period the sewage increment is removed entirely on all domestic consumption over the average consumption for the coldest winter months. Water consumption during the summer rate months, up to this base amount, is charged at the regular water and sewage rate; all water above the winter base amount is charged at a slightly reduced "water only" rate. In other words, not only is the sewage charge removed, but the base rate for water is slightly reduced so the term "summer rate" bears validity.

Although this method of obtaining revenue may not be entirely fair in the more minute details, it produces revenue sufficient to bear the actual cost of supporting these facilities on a more equitable basis than valuation. Schroepfer (1) covered this question most thoroughly; and it is on the principle of the Joint Committee of the American Bar Association and the ASCE (2) that K. F. Hoefle, Superintendent of the Dallas Water Department, established the present Dallas water and sewage service rates.

Industrial Accounts

The inequity lies in the industrial increment of sewage, and the sewage rate is under study to establish an industrial rate including the strength factor. In this particular case the item is not as important as it may be in other cities, because the Dallas area has little heavy industry. In fact, local industry is more of the assembly, or dry products type.

If an industry objects to a sewage charge where a considerable part of the water consumed is not returned to the sewer, that industry is given the privilege of submetering the process at its own expense. The Department will read these meters and deduct the flows from the master meters.

Vacant Properties

A source of revenue is being missed in vacant property not utilizing facilities available to it. The tax department is not overlooking this source of income, however, and promptly increases valuation when a sewer or water line is constructed in front of vacant property. To date, it has not been possible to convince them that such increases belong in the waterworks fund. It is encouraging to know, however, that this item is not entirely overlooked in the common interest. When the customer finally connects, he is required to pay the current pro rata charge based on current construction costs of 8-in. sanitary sewers, so the sewage division ultimately gets its share.

Further Benefits of Combination

Combination of facilities also has proved more beneficial as regards assignment of mechanics, electricians, and shop phases. Combined shop facilities for both water and sewage treatment and pumping are a real economy in the Dallas operation. It allows pooling of personnel and equipment of a higher caliber than could be afforded under

separate activities. By use of these personnel interchangeably, a combined preventive maintenance program can be more easily implemented.

In this regard, it is felt that preventive maintenance is one of the best signs of good management at plant level. The sewage treatment plant whose structures and equipment are maintained on a routine and planned basis is visible and immediate evidence of good management—and generally the well-maintained plant is equally as well run. The supervisor of sewage treatment who has the ability to catalog all of the necessary maintenance operations, weigh these against available labor forces, and come up with a planned uniform work load assuring continuity of operation of his facility, is demonstrating the real qualities of good management.

Outstanding results have been produced with a planned maintenance program at the Dallas sewage treatment plant. For example, removal of units from service for routine maintenance inspections more than once has revealed that an unsuspected failure was imminent. With preventive maintenance, it was possible to correct all sources of trouble before breakdown occurred, and at a time when its was convenient.

Better Use of Manpower

In addition to the prevention of breakdown, distribution of available manpower to necessary work is being effected. Although more work is being done with preventive maintenance, it is found that the end to more emergency breakdowns gives the time to carry on preventive maintenance with the same number of people. Often, the big problem in initiating preventive maintenance programs is finding enough people to start maintenance and take care of the emergency breakdowns occurring at the same time. The only answer is temporary personnel or overtime. Once the barrier is broken and emergencies are reduced, no one is known who has put in a maintenance program with any degree of determination to make it work that has not found life much more pleasant.

Logical Association

It is realized that most units operating as separate departments have no particular desire to effect an immediate merger with the local water departments. At Dallas, the necessity for tax increases to adequately support the vital need for sewage service was more distasteful than an increased water rate. Therefore, the Sanitary Sewer Department was transferred from the Public Works Division to the Water Department. In the Water Department, under the combined rate mentioned previously, it has always received adequate income for its support and operation. So, if any municipality is in the midst of reorganization plans, it may be heartening to know that the two fields are not as far apart as might first be imagined. Surely treatment and collection of sanitary sewage have more in common with purification and distribution of water than they do with streets and storm drainage.

Personnel Problems

It was mentioned, by way of introduction, that the people doing the jobs are even more important than the investment in plants and equipment, and that the best plants and collection systems function only as well as the people who run them. If a job is of any magnitude, it can't all be done by one person. There comes a time when problems have to be handed to subordinates with the expectation that they will have the interest, imagination, and ability to carry the job through to a satisfactory conclusion. The bigger and faster a unit grows, the more this has to occur.

Pay Adjustments

New jobs, new responsibilities, and organization always bring up the problem of wage and salary adjustments. The question is how to set a wage

schedule which will compete with private utilities—and in adjustment, how to eliminate inequities in pay which have arisen during the past 20 years.

Most cities have found job evaluation to be the most effective and accurate means of accomplishing this. This process is by no means simple, but properly administered it should result in an equitable redistribution of available payroll funds on the basis of job value and responsibility.

Briefly, this program must begin with a complete written job description. The duties and responsibilties are then condensed into job requirements on the basis of the minimum requirements expected of an applicant for the job. Four factors are considered: pre-job training, on-job training to be expected, responsibility, and physical hazards or demands. Quite often, evaluation programs break these down into the five factors of (a) mental requirements, (b) skill, (c) responsibility, (d) physical effort, and (e) working conditions.

Choosing a number of representative jobs so described, a total point value is assigned to each, the number of points being a factor of salary. A committee then begins the process of taking these jobs and distributing the total assigned points to each job factor—in other words, what is to be paid for (risk, education, skill, responsibility, or what the employee has learned or will learn on this job).

Then comes the task of taking other jobs and comparing the value of each factor to find the job it compares with. The net result is that a job may compare with a graduate engineer on pre-job training, with a clerk on on-job training, with an office manager on responsibility, and with a ditchdigger on hazard and disagreeable working conditions. When all of the points are added up, that establishes a particular place in the evaluation scale. Such a comparison of all jobs, plotting present pay against evaluated points, gives a "scatter diagram," which plainly points out cases of underpay and overpay.

From then on, the statisticians and personnel people must establish rates of progression, and median salary scales to fit the wage and salary schedule to available funds and market prices.

The procedure sounds formidable, but it appears to be about the fairest way of getting things straightened out. A word of warning is in order, however. An impartial committee should be selected; if composed of employees, they must not participate in evaluation of jobs in which they have a personal interest. An evaluation committee can well be compared to a jury: it should have no preconceived opinions, for if such be the case, comparative evaluation will be distorted. If one committee member oversells a job, he can bring a whole category of classification out of line with it. Obviously, the job is to correct such errors, not to create new ones.

Reorganization Problems

Reorganization to meet increased demands for service also brings new job duties and ways of doing things. This has been felt most keenly recently in the Dallas business office, where billing, accounting, and most of the public contact of the department occurs. It has been found necessary to expand this office and employ a trained business manager. It is his duty to study and analyze each phase of billing and accounting and public contact.

All of the procedures and methods are presently under study, not only to reduce to an absolute minimum the loss of time and motion in handling service records necessary to serve 140,000 accounts, but also to see that they are handled in the courteous manner which will impress each customer that publicly-owned services can be efficient. Customer relations and office procedures have been emphasized by recent conversion to the IBM method of bill-

ing. In the implementation of this system, reorganization of jobs and work procedures was a must. Nearly everyone himself doing things a different way. High turnover and the difficulty of recruiting new personnel were factors during this entire conversion, and still remain a major problem.

In-Service Training

The conclusion has been reached that in-service training on all of the Department's jobs not only will result in better job knowledge, but will get new people on the job in a hurry. Such programs can be of invaluable assistance in giving the new employee proven ways and means of answering the many customer questions that are bound to occur again and again. Everyone has found that certain approaches to a customer's complaint are the most successful. Also, most complaints fall into general types—odors, surcharging, or delays in making extensions. A short training course, with written outline to give the new employee the benefit of an "old timer's" experience, can be of real and lasting benefit. Desk manuals are being written for each job, to help the new employee. Also, many of the old employees find in-service programs can be of real value.

Each supervisor holding such a course can solicit a discussion of problems and delays occurring in each phase of operation. After all, the person doing the job probably knows more about it than anyone else in the organization. Certainly his comments and suggestions, when properly encouraged, will not result in just gripes. In addition, teamwork in ironing out these problems brings new enthusiasm for doing the job well. Old employees can be periodically scheduled for service training meetings when a change in procedure in some phase of the organization is planned. Each clerk handling customer complaints must have a thorough knowledge in the working of all divisions. Keeping him acquainted with just how his work affects other operations is of real value to over-all efficiency.

Training in Courtesy

In connection with this training, one very important phase, which management must not overlook, is that of training and retraining the employees in courtesy. To the citizens calling the department for the first time, the clerk on the other end of the telephone bespeaks the professional ability of the superintendent, as well as his efficiency as an administrator. The caller is going to form his opinion of the head man and the department largely upon what kind of reception he receives and how well his complaint is handled. Anyone is overlooking a big chance to sell his job and himself to the public if he underestimates the value of telephone courtesy in his office. One course is not enough: there must be constant training and coaching.

Where the customer is contacted in the office, there is an equally or even more difficult public relations problem. Here facial expression as well as voice inflection is important, and special training of these employees is required. They all need to be trained and coached on how to handle certain problems or complaints most diplomatically. It is necessary to get together with the employees and discuss how certain difficult situations were handled successfully.

These things must not be thought of as lost time or waste of money. They are a most valuable demonstration of efficiency and willingness to serve, which is the real job. An excellent film is available on telephone courtesy, which was produced by a New York firm. One of the factors which the film discusses, and which most employees will find out for themselves, is that courtesy pays dividends, and actually makes the job easier. The customer who is particularly upset by some breakdown in service and is met by a

pleasant employee who demonstrates by voice and actions that he is eager to help, can make a great deal of difference whether the interview waxes hot or the citizen leaves impressed with the way his utility is handled.

Those who have switchboard operators certainly must have noticed how easy it is for a customer to be further enraged by bungling of his telephone call or curt treatment when his call to the department is first acknowledged. A warm reception is bound to soften even the most hardened complainant. This is true in all divisions of the department. The chemist at the plant, when receiving inquiries from the public, has an opportunity to make a good impression for the department as a whole. Is is earnestly suggested that this matter be given a great deal of thought in the reader's own circumstances. Not only will reception of the public improve by instilling in the personnel an eagerness to serve, but a desire to improve service also generally will result because employees will begin to think of the operation in terms of what displeases the public and how this can be changed or improved.

Conclusion

In closing, it should be repeated that a sewage works should be thought of as a business; that management should devote itself to operating it as one. The aims and objectives in studying the particular administrative procedures should be to improve the efficiency of the operation. In addition, it is necessary to work towards establishing rates which will adequately support the utility as a utility, and in the manner which it deserves.

Among the requisites is to arm oneself with statistical and financial data which will enable a clear presentation of the problems to city councils and municipal managers. The city council needs to know what a certain new development will mean in terms of new plants, trunk sewers, and pumping stations. They need to be cautioned as to what the limits of expansion will be before a major capital improvement program will be necessary. Managers of sewage works must anticipate and sell present costs on the basis of what ultimate cost will be, as any business would do, instead of waiting for overloading of facilities to occur, then calling on a guiltless generation to bear an unjustifiable debt service and capital expenditure.

The fact might as well be faced that if an individual is going to supervise a sewage works operation, he must leave the technical aspects of plant operation largely to personnel trained specifically in that field, maintaining only general administrative control. Superintendents of these works must look more to the major factors of people, finance, and methods of administration if they are to successfully carry out their intended work.

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DISCUSSION

By Van Porter Enloe

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As Mr. Graeser points out, fast growth brings management problems, as well as technical problems, to any utility or business, and the urban population increase throughout the United States has been remarkably fast. It is also true

that the subject of management has been neglected, although papers and discussion on certain phases of the subject (that is, public relations, plant housekeeping, financing, operators' salaries, etc.) have appeared in the literature from time to time.

For emphasis, there are first repeated what are believed to be the high lights of Mr. Graeser's paper, as follows:

1. Command, as he defines it, if handled in the spirit and with the attitude toward the subordinate that his definition suggests, should be the difference between a happy organization where every man is proud of his job and his department, and a situation where every man is looking out for himself and "Devil take the hindmost." It is the difference between a situation where cooperation for better service to the customer takes precedence over his "jockeying for position." It tends toward a situation where good housekeeping in the plant, good laboratory control, good feeling amongst the employees, and good engineering of sewerage are all of equal importance. It is all just good management.

2. Certainly the value of the service to a community that a sewage works performs, which increases year by year as the standards of living improve, the mechanization of the homes and industry increase, the responsibility for pollution abatement is accepted, and the sewage works grows more monstrous in size, should be recognized, and the organization should take its place as a public utility.

Atlanta has five sewage treatment plants whose total cost to the city was a little more than $2,000,000. There are also 1,208 mi. of trunk and lateral sewers, costing approximately $14,000,000 and serving 602,000 people. This service can easily be recognized as a utility. At the last Georgia Water and Sewage Association Short School, a city of 5,000 population was pointed out as having a sewage treatment plant costing $180,000 and a sewage collection system costing $625,000; thus, even in a small city, that large an investment should put its sewage works in the utility bracket.

3. As to preventive maintenance, Atlanta in the last year has undertaken the job of assuming the responsibility for over 100,000 more population, and 82 additional square miles of territory. Hundreds of employees and large quantities of equipment and real estate were taken over from the county. Absorbing a share of this responsibility has considerably bogged down the program of preventive maintance. But the value of such a preventive maintenance program has been proven, because without it there would have been numerous breakdowns during this change. Preventive maintenance is a step ahead in plant operation.

The Atlanta sewage works is a metropolitan system participated in by five adjoining cities and other county areas. It is a division of the Construction Department, under an Engineer of Sewers. The Construction Department, under a Chief of Construction, an engineer, is the Public Works Department of the city. Those in the Atlanta sewage works believe that this is the best setup for the system, as their engineering problems are more nearly the same as those of storm sewers, streets, bridges, and construction. Besides, the shop and maintenance problems combine better with those of the named services. Moreover, they like having an engineer as chief, on the belief that it is easier to make a politician out of an engineer than to make an engineer out of a politician.

The group also believes that sewage works management is engineering, and although it is not believed that Mr. Graeser meant to imply otherwise, the manager of a sewage works, or a waterworks, or a combination of both, should

be an engineer to fairly and satisfactorily analyze and present the problems of either.

As a sewage plant operator, it is not easy for the writer to see the fairness to the sewage works of having the water and sewage bill in one package. He cannot help but believe that financing both through the water bill would tend to magnify the importance of waterworks over sewage works to the taxpayer and the City Fathers. His own preference would be to work in a sanitary district, where sewage service charges are collected as such.

This provocative paper should suggest to all a re-study of their respective organizations.

SEWAGE WORKS FINANCING IN WEST VIRGINIA

"Methods of Financing Sewers and Sewage Treatment Works in West Virginia" is the title of a recent 72-page report on the subject prepared by the Bureau for Government Research, University of West Virginia, and published by the West Virginia State Department of Health and the State Water Commission.

After discussing the problem of pollution in West Virginia and outlining the areas of responsibility of the various agencies concerned with pollution control at the federal, interstate, and state levels, the report discusses in detail the problem of where cities are to get the money to finance needed projects. Besides allotments from the general funds, such means of raising money as general obligation bonds, special assessment bonds and certificates, revenue bonds, and sewage service charges are discussed.

Also covered are the financing problems of the small incorporated and unincorporated areas. Under this category are given the pros and cons of the sanitary district, as well as some alternative plans. The report closes with recommendations for amendment of existing statutes to correct fundamental weaknesses, merging of certain statute provisions for clarity, and provision of adequate fiscal power for county courts to construct or acquire sewage works.

An appendix summarizes the methods of finance, with resumés of the legal provisions governing general obligation bonds, revenue bonds for municipal public works, sewage works and municipal corporations, and sanitary districts, combined waterworks and sewage systems, sewage service charges, and improvement assessments.

A second appendix tabulates the status of sewage treatment improvements in each incorporated city, town, and village in the various major drainage areas of the state.

REMOVAL OF TOXIC MATERIALS BY SEWAGE SLUDGES*

By Willem Rudolfs and A. L. Zuber

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Adsorption or zeolitic action as a responsible agent for a portion of the purification accomplished during biological treatment of sewage has been accepted as fact, but little work has been done on use of sewage sludges or biological growths to treat metal-containing wastes. Exceptions to this are the recent investigations on the utilization of biological methods to dispose of radioactive wastes.

In the activated sludge process for sewage purification a rapid removal of material occurs within the first 30 to 60 min. This clarification has been ascribed to a physical process in which removal is effected by the active floc. There is a difference of opinion, however, as to the mechanism of the removal. Agreement is also lacking concerning the causative factor. The process may be one of strict surface adsorption or may involve a base exchange reaction. The role of causative agent may be attributed to an inorganic zeolite in the sludge matrix, to the organic matter, or to the microorganisms in the zoogleal mass.

Copper, zinc, and chromium have been successfully treated by ion exchange methods. Although these metals have a toxic effect on biological systems, the possibility exists that such systems by means of their adsorption or zeolitic capacities may be able to remove the toxic materials from solution.

This paper is concerned with the possibility for such removal, the rate at which it is accomplished, the effect of the toxic metals on biological growths, and the principle responsible for the removal.

Many theories expounding rapid clarification of sewage when in contact with biological growths are enumerated by Theriault (13). Dunbar (3) in 1897 concluded that "an explanation of the purification process must be sought in adsorption phenomena." The principal points of Dunbar's theory are that (a) surface attraction causes the transfer of coarser particles to the biological growths, (b) dissolved materials are retained by adsorption phenomena accelerated by the growth of the biological mass, and (c) the adsorption process is maintained by the action of microorganisms under aerobic conditions. Jones and Travis (6) at first held that solids were deposited because of the action of surface as such and not because of the colloidal properties of the biological growths, but later acknowledged that the colloids in gel form found in the biological growths encouraged further deposition and thus biological growths played a part in the clarification process. Parsons (9) concluded that the clarification stage of the activated sludge process approximately follows the adsorption isotherm of Freundlich.

During their investigations concerning stream pollution, Theriault and McNamee (16) found that when the grossly polluted water trickled over slime covered stones a highly clarified liquid was obtained in 20 min., but 10-day incubation in the absence of biological slime was necessary to accomplish a like degree of purification. They concluded that the floc itself was the primary adsorbent apart from im-

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

bedded bacteria, secreted enzymes, or attending protozoa. Theriault (14) contended that the adsorbent principle in activated sludge is a base exchanging substance similar to the zeolites used in water purification and having the formula:

$$0.84\,M_2O \cdot R_2O_3 \cdot 3\,SiO_2.$$

Later he extended this theory (14), stating that adsorption by activated sludge is not due to any versatile enzyme or to the action of surface as such, but that the aluminosilicate complex or sludge zeolite is wrapped around the bacteria to provide an adsorptive coating of known characteristics. Adsorption of ammonia, amino acids, lignoproteins, etc., can be explained in terms of base exchange. Theriault and McNamee (16) offered the following evidence for the existence of a zeolite in activated sludge: (a) equilibrium is reached between the sewage and sludge in a short time (30 to 40 min.), (b) sludge possesses the jelly-like and water retaining properties of a partly dried zeolite, and (c) the chemical composition of the sludge, apart from the imbedded bacteria, is essentially that of a zeolite. According to their data the adsorption of ammonia and organic matter by activated sludge follows the Freundlich isotherm. They concluded that adsorption is due to the aluminosilicate complex, either acting singly as an inorganic zeolite or partly combined with lignoproteins as a humic aluminosilicate.

Setter *et al.* (12), investigating the cation exchange capacity of activated sludge, reported that adsorption is due to the exchange of a mobile ion of the sludge matrix with a like, immobile, or more strongly associated colloidal sewage ion. Both the sewage colloids and the floc particles are negatively charged. The product of the quantity and intensity of cation dissociation is greater than that of anion dissociation. Thus, a given portion of sludge matrix may be distinctly negative in character, because of the cation dissociation, and would favor cation exchange with sewage colloidal cations to form a more stable or a less dissociated complex. Activated sludge is amphoteric in nature.

Baly (1) advanced the theory of mutual flocculation. In distilled water, sewage colloids have an isoelectric point of 4.6. An increase in the electrolytes in solution causes an increase in the isoelectric point. In a 3 per cent NaCl solution, the isoelectric point is at pH 8.3. Most sewage colloids bear a slight negative charge. Under normal operating conditions with a sewage of pH 7 to 8, sludge is highly electronegative, sewage colloids slightly electronegative; the latter are flocculated on the activated sludge particles and coprecipitation occurs. As a result of bacterial metabolism, soluble crystalloid salts are produced. These raise the isoelectric point of the sewage colloids, making the charge on them less electronegative and thus the flocculation is assisted.

Lumb (7) believes that this theory has some merit. Acid treatment of sewage to lower the pH, and thus reduce the electronegativity of the charge on the sewage colloids, should raise the efficiency of the activated sludge process. Laboratory work showed that efficiency was greatest when the mixed liquor had a pH of 6.5. Increasing or decreasing the pH decreased the efficiency.

Heukelekian (4) found that inorganic materials such as infusorial earth and kaolin are removed from suspension by 1-hr. contact with activated sludge in the presence of air; that organic materials such as butyric acid, dextrose, peptone, casein, and egg albumin are removed to a small extent, which may be due to bacterial action rather than adsorption; and that ammonia removal is not due to a physical process. The last point was corroborated by Corbet and Wooldridge (2), who found that the amount of ammonium nitrogen adsorbed by activated sludge was greatest shortly after the

addition of fresh sewage and decreased as the treatment proceeded.

Studies on the ammonia uptake by activated sludge reported by Ingols (5) show that activated sludge prepared by electrodialysis prior to mixing with ammonia or washing with NaCl solution adsorbed ammonia to the extent of 3 mg. per gram of activated sludge. Wet, treated sludge, which removed NH_3-N before drying, failed to do so after drying because of changes in the surface during the drying operation, and sludge in which organisms were killed by electrodialysis, by exposure to salt solution, or by drying, adsorbed ammonia. Adsorption can also take place in the presence of chloroform. Hence, the physical process is independent of biological activity. Ingols agrees with Heukelekian that during aeration the removal of ammonia by the activated sludge is due to bacterial action; because ammonia is the least strongly retained of any cation by the zeolite, an ammonium zeolite will most readily adsorb other cations. Removal could not be due to base exchange, because in normal sewage the sum of the concentrations of sodium, potassium, and calcium ions is greater than the concentration of ammonium ions. Similar reasoning precludes zeolitic action to account for ammonia removal.

Further, microorganisms utilize glucose along with ammonia to fabricate protoplasm, and the presence of glucose stimulates the uptake of ammonia, indicating that biological activity is responsible. Finally, chloroform blocks completely ammonia uptake.

Ruchhoft (11) has demonstrated that the principles underlying clarification by activated sludge may be extended and the process used to treat radioactive wastes. Experiments showed that when sewage containing plutonium was treated by activated sludge, a 96 per cent reduction in the alpha count could be effected.

McGeorge (8), investigating base exchange reactions attributable to organic materials in soils, found that the exchange capacity of highly organic soils is a linear function of the percentage of carbon in the soil. No such relationship exists between the exchange capacity and the nitrogen content or the nitrogen-carbon ratio. If the soil is digested with H_2O_2, the loss in exchange capacity is proportional to the amount of organic matter destroyed. Base exchange reactions attributable to the organic matter in soils take place in chemically equivalent proportions.

Procedure and Methods

During the course of these studies, activated sludge, ripe sludge, and fresh solids were obtained from various sources. After the total solids contents of the sludges were determined, the materials were diluted with distilled water to the desired concentrations, and hexavalent chromium, zinc, and copper were added. Upon addition of the toxic metals the mixtures were aerated to insure contact between the sludge and the toxic material. The solids were allowed to settle and the supernatant liquor was decanted and used for further study.

Total solids, ash content, alkalinity, and sludge volume index were determined according to "Standard Methods" (18); chromium was determined as barium chromate, zinc as the pyrophosphate, and copper colorimetrically by the carbonate method. Turbidity was determined with the Fisher electrophotometer, standardized against the Jackson turbidimeter.

Removal of Toxic Metals by Activated Sludge

Hexavalent Chromium

To a series of duplicate activated sludges with concentrations of 500, 1,000, and 2,000 p.p.m., various quantities of chromium were added in the form of potassium chromate. The mixtures were aerated for 30 min., allowed to settle, and the effluents tested for chromium. Although chromium was absorbed, erratic results due to difficulties encountered in the analysis of

TABLE I.—Removal of Zinc and Copper by Activated Sludge; 30-Min. Contact

Act. Sludge Conc. (p.p.m.)	Zinc			Copper		
	Added (p.p.m.)	Removed		Added (p.p.m.)	Removed	
		(p.p.m.)	(%)		(p.p.m.)	(%)
500	7.5	6.25	83.3	33	23.8	72.1
500	15	5	33.3	54.5	17	31.2
1,000	7.5	7.5	100	33	29.7	90
1,000	15	11.7	78	54.5	29.7	54.5
500	7.5	7.5	100	33	29.7	90
1,000	15	11.7	78	54.5	50.7	92

chromium remaining in the effluent precluded conclusions respecting the exact removal of this metal by activated sludge.

Zinc

Zinc is readily removable from solution by activated sludge. The removals effected are summarized in Table I.

Copper

Copper in the form of copper sulfate was added to activated sludge in concentrations of 33 and 54.5 p.p.m. (Table I).

Obviously, zinc and copper are readily adsorbed by activated sludge and there seems to be a relation between the concentration of the activated sludge and the amount of toxic material removed from the liquid.

Effect of Contact Time on Removal of Copper

Activated sludge was diluted with distilled water to concentrations of 1,000 and 2,000 p.p.m. suspended solids. To one duplicate set of mixtures at each concentration, 27.5 p.p.m. of copper were added, and to two other duplicate sets, 55 p.p.m. of copper. To determine the rapidity of removal of the copper, duplicates in each set were aerated for different periods of time. The aeration periods used were 5, 10, 15, 20, 25, and 30 min. The results obtained are presented in Table II. Apparently the amount of copper removed is, within limits, a function of the concentration of activated sludge and the time of contact.

Effect of Character of Activated Sludge upon Removal of Toxic Metals

To determine the effect of the character of activated sludge on the rate of removal of toxic materials, a series of experiments was made in an effort to correlate the type of biological growth developed with the adsorption capacity. A series of 47 separate runs was made until the quality of the activated sludge deteriorated to such an extent that in the last batches sludge expansion was so great that practically no settling occurred. As an indication of the changes in adsorption capacity of zinc, a few results obtained are shown in Table III. The amount of zinc removed decreased as the sludge

TABLE II.—Percentage Removal of Copper by Activated Sludge

Act. Sludge (p.p.m.)	Aeration Period (min.)					
	5	10	15	20	25	30
(*a*) 27.5 P.P.M. Copper Added						
1,000	68	83.5	85.5	87	91.5	93
2,000	64.5	82	84.5	87.5	89.5	89.5
(*b*) 55 P.P.M. Copper Added						
1,000	49	62	63.5	65.5	65.5	65.5
2,000	54.5	69	78	86.5	89.0	94.5

TABLE III.—Removal of Zinc[1] by Activated Sludge[2]

Date	Act. Sl. Index[3]	Zinc Removed (p.p.m.)
8/17	400	6.7
8/25	450	7.0
8/30	980	0
9/9	980	0

[1] 15 p.p.m. Zn added.
[2] 1,000 p.p.m.
[3] Sludge volume index.

volume index increased. The last two batches, very bulky in nature, failed to remove any zinc. It appears that the condition of the biological mass is definitely connected with the removal capacity of the sludge. The microflora and fauna found in bulky sludge differed greatly from those found in the good sludge. The process involved is not simply one of base exchange, but rather involves biological activities, the different organisms exhibiting diverse behaviors in the presence of toxic metals. Possibly, also, different types of living organisms absorb the toxic substances at different rates.

Effect of Toxic Metals on the Sludge Volume Index

In an effort to correlate the volume as well as the weight of the activated sludge with its adsorption capacity, copper and zinc were added in different quantities to varying concentrations of sludge.

Copper acts as a compacting agent toward activated sludge. After 30-min. contact, the resultant sludge index is approximately 50 to 60 per cent of the original index. This effect is shown in Table IV. The lowering of the index manifests itself after 5-min. contact with copper, the lesser index remaining practically constant despite longer contact times (Figure 1).

TABLE V.—Effect of Repeated Additions of Copper on the S.V.I.

Cycle No.	Activated Sludge (p.p.m.)	
	1,000	2,000
(*a*) 27.5 P.P.M. Copper Added per Cycle		
0	220	430
1	150	260
2	120	200
3	120	170
(*b*) 55 P.P.M. Copper Added per Cycle		
0	220	430
1	150	360
2	130	210
3	120	175

If the same batch of activated sludge is repeatedly subjected to contact with additional charges of copper, a further lowering of the sludge index is caused by each additional charge of copper (Table V).

Zinc does not have as great an effect on the sludge volume index as does copper. Even a slight increase in the index may occur after contact with zinc (Table VI).

The effect of copper on the sludge volume index becomes apparent after 5-min. contact and then remains practically constant, but with zinc this is not the case. In general, the resultant sludge index shows some tendency to decrease with an increase in contact time.

As in the case of copper, repeated additions of zinc to the same batch of ac-

TABLE IV.—Effect of Copper on the S.V.I.; 30-Min. Contact

Act. Sludge (p.p.m.)	33 P.P.M. Cu Added			54.5 P.P.M. Cu Added		
	Before	After	% of Orig.	Before	After	% of Orig.
500	180	120	66.6	200	120	60.0
1,000	200	130	65.0	240	120	50.0
2,000	315	175	55.5	375	180	48.0

TABLE VI.—Effect of Zinc on the S.V.I.; 30-Min. Contact

Act. Sludge (p.p.m.)	7.5 P.P.M. Zn Added			15 P.P.M. Zn Added		
	Before	After	% of Orig.	Before	After	% of Orig.
500	180	160	89.0	200	160	80.0
1,000	200	210	105.0	240	220	92.0
2,000	355	305	86.0	330	365	110.0

tivated sludge cause a progressive decrease in the sludge index, although an increase may occur after the first cycle.

Capacity of Activated Sludge for Removal of Metals

Although a given concentration of copper or zinc added to a given concentration of activated sludge is known to result in a definite percentage removal of the metal, two questions still remain unanswered. These are:

1. After removing a toxic metal can the same batch of activated sludge remove still more of that metal if an additional charge of that metal is introduced?

2. Can the activated sludge be regenerated with sodium chloride and thus have its capacity for further removal increased?

To determine the sludge capacity, the following procedure was used. Activated sludge was diluted to 1,000 and 2,000 p.p.m. with distilled water. To cylinders, each containing 1 l. of the diluted sludge, concentrations of 27.5 and 55 p.p.m. of copper and 7.5 and 15 p.p.m. of zinc were added. After the metals were added, the mixture was aerated for 30 min. and allowed to settle. Portions of the effluents were withdrawn for testing and the remainder decanted. The sludges were washed with distilled water for removal of metal-bearing supernatant liquor, the sludge being allowed to settle between washings. After being washed, the sludge was rediluted with distilled wa-

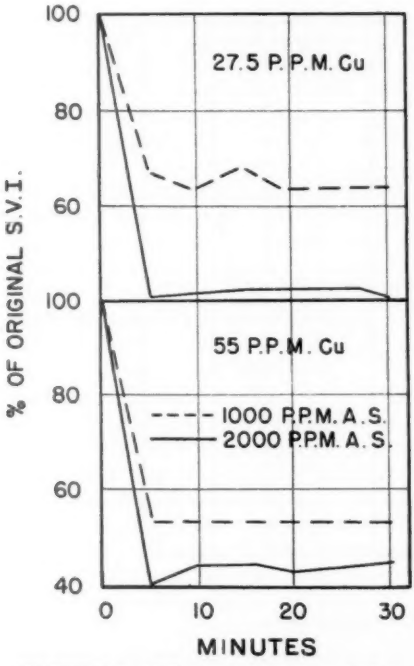

FIGURE 1.—Effect of copper on sludge volume index.

TABLE VII.—Capacity of Activated Sludge; 30-Min. Contact per Cycle

Act. Sludge (p.p.m.)	Metal Added per Cycle		Metal Removed[1] After Cycle		
	Type	(p.p.m.)	1	2	3
1,000	Cu	27.5	23.5	12.5	2.0
1,000	Cu	55	31.5	3.75	[2]
1,000	Zn	7.5	3.9	1.6	0.1
1,000	Zn	15	5.1	3.4	2.5
2,000	Cu	27.5	27.0	22.7	10
2,000	Cu	55	54.0	3.6	[3]

[1] Metal removed, in p.p.m.

[2] 55 p.p.m. Cu added; 65 p.p.m. Cu found after aeration.

[3] 55 p.p.m. Cu added; 82 p.p.m. Cu found after aeration.

ter, toxic metal was again introduced, and the procedure repeated. Three such cycles were run on each batch of activated sludge.

Data presented in Table VII indicate the removals of copper and zinc effected. The total removals of copper by the three cycles of activated sludge at both concentrations used show a striking similarity in the total removal possible. With 1,000 p.p.m. of activated sludge when 27.5 p.p.m. of copper were added per cycle, the total removal was 38 p.p.m.; when 55 p.p.m. of copper were added per cycle, total removal was 35.25 p.p.m., exclusive of any removal that may have taken place in the third cycle.

At a concentration of 2,000 p.p.m. of activated sludge and 27.5 p.p.m. of copper per cycle, total removal amounted to 59.7 p.p.m. When 55 p.p.m. of copper were added per cycle, a total of 57.6 p.p.m. of copper were removed, exclusive of any possible removal during the third cycle.

To determine whether it was possible to regenerate the activated sludge after it had caused the removal of a toxic metal and thus to increase its capacity for further removal, the following experiments were carried out.

The same procedure was followed as previously described, except that washing of the sludge between cycles was done with various concentrations of a salt solution, rather than with distilled water. The results show that in all cases washing with salt solution between cycles caused a slight increase in the capacity of the activated sludge. As an illustration, some of the results are graphically shown by Figure 2.

Removal of Copper by Ripe Sludge and Fresh Solids

Theriault (15) has reported that the inorganic colloids in sewage and in

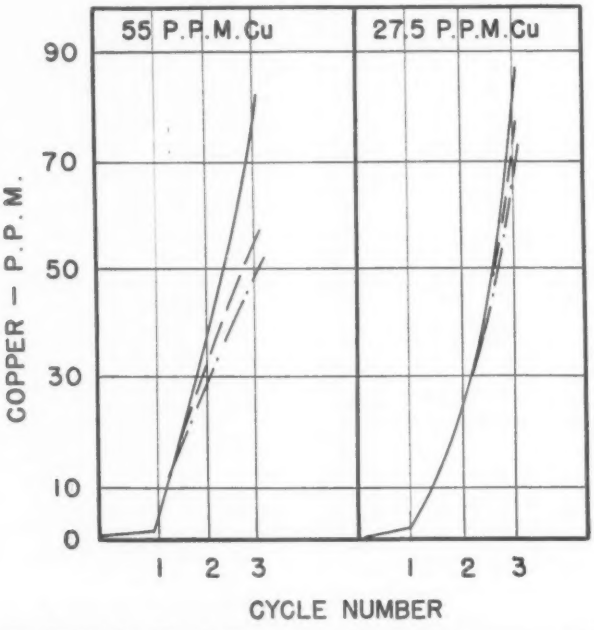

FIGURE 2.—Copper in effluent after each washing cycle: ———— washed with distilled water; — — — — washed with 55 or 27.5 p.p.m. NaCl; —.—.—. washed with saturated NaCl solution.

TABLE VIII.—Removal of Copper by Ripe Sludge[1]

Copper added (p.p.m.)	30	60	120	180
Copper removed (p.p.m.)				
Sludge and supernatant	23	37	50	45.5
Supernatant	14	22	31	27.5
Sludge	9	15	19	18

[1] 1,000 p.p.m. sludge.

settled sewage sludge possess essentially the same chemical composition as the activated sludge zeolite. During his studies on the clarification stage of the activated sludge process, Ingols (5) concluded that the organic matter in the sludge, rather than an inorganic zeolite, was responsible for the rapid removal of material manifested during this phase of the process. Regardless of which of these two divergent hypotheses is correct, the inference is that other biological materials, such as ripe sludge or fresh solids, should cause a removal of toxic metals, such as copper, similar to that obtained with activated sludge.

To determine whether toxic metals were adsorbed, ripe sludge was diluted to concentrations of 1,000 p.p.m. with distilled water, and copper in the form of copper sulfate was added in concentrations of 30, 60, 120, and 180 p.p.m. Cu. An important factor to be considered is the effect of the supernatant liquor in the removal of the toxic metals added. The liquors above activated sludge, ripe sludge, and fresh solids contain substances in solution which may possibly be responsible for all or part of the removal attributed to the biological material, since these substances may react with the metals and cause their removal by precipitation. In the case of both activated sludge and fresh solids, the supernatant liquors were found to have no effect on the removal of the metals. However, the ripe sludge liquor was found to be responsible for approximately 60 per cent of the removal effected. As an example, the removals of copper caused by 30-min. contact with ripe sludge are enumerated in Table VIII.

Fresh solids diluted to 5,000 p.p.m. and treated with copper in the same concentration as used with ripe sludge showed definite removals after 30-min. contact, as indicated by the following:

Copper Added (p.p.m.)	Copper Removed (p.p.m.)
30	29.5
60	58.0
120	100
180	102

Role of Organic Matter in Removal of Copper

McGeorge (8) found that the base exchange capacity of soils was directly related to the organic matter content. Ingols (5) named organic matter the causative agent in the adsorption of ammonia.

Ripe sludge, fresh solids, and activated sludge obtained from various sources were used to determine whether such a relationship existed in the removal of copper by these sludges. The sludges were diluted to concentrations of 20,000, 10,000, 5,000, 2,000, and 1,000 p.p.m. with distilled water, and copper was added to each dilution in the ratio of 60 p.p.m. per 1,000 p.p.m. suspended solids. The mixtures were aerated for 30 min., and the residual copper in solution was determined. The removals caused by the three sludges, plotted as function of the solids concentration irrespective of their volatile matter contents, are illustrated in Figure 3. It

TABLE IX.—Copper Removed (P.P.M.) Per 1,000 P.P.M. of Volatile Suspended Matter

Solids Conc. (p.p.m.)	Copper Removed (p.p.m.)[1]		
	Fresh Solids	Ripe Sludge	Activated Sludge
20,000	25	27	38
10,000	23	27	38
5,000	24	30	37
2,000	24	22	38
1,000	28	28	39
Av.	25	27	38

[1] P.p.m. per 1,000 p.p.m. volatile suspended matter.

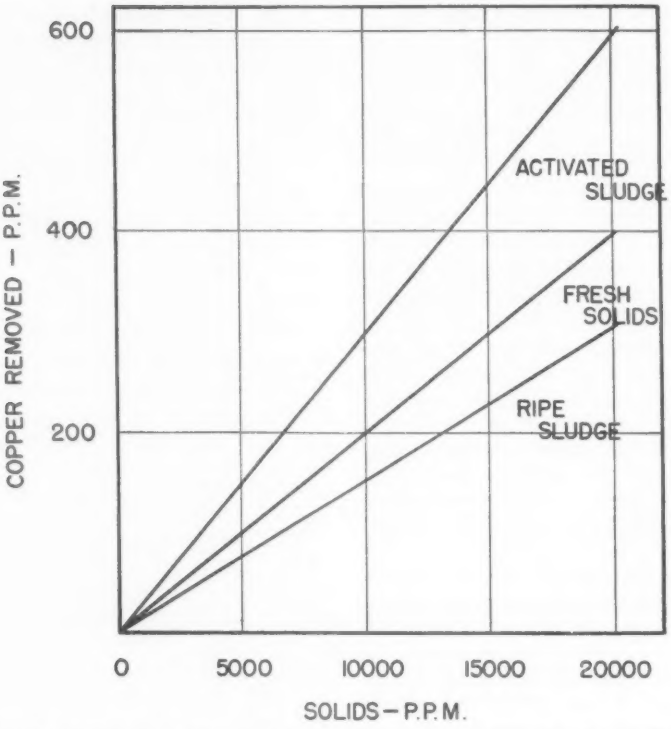

FIGURE 3.—Removal of copper by various concentrations of different sludges.

appears that there is a linear relationship between the sludge concentration and copper removal.

If the removals effected by the fresh solids, activated sludge, and ripe sludge are calculated on the basis of parts of copper removed per 1,000 parts of volatile suspended matter, a very noticeable similarity manifests itself, as shown in Table IX. No such agreement exists if removals are calculated on the basis of the ash content of the three types of materials.

Discussion

Adsorption or zeolite action may be postulated as the mechanism responsible for the rapid removal of material which occurs during the clarification stage of the activated sludge process. Metals can be removed from solutions of their salts by utilization of this faculty of the activated sludge, fresh solids, and ripe sludge. Copper and zinc are readily removable. Electrophoretic measurements show that the activated sludge particles bear a negative charge. An attraction should exist between these floc particles and the positively charged copper and zinc ions, and thus their removal should be effected.

The data presented show that the amount of either zinc or copper removed is a function of two factors: the concentration of the sludge and the time of contact between the sludge and the metal.

At the lower concentration of zinc employed, 7.5 p.p.m. total removal was effected by 1,000 p.p.m. of activated sludge after 30-min. contact. Complete removal of copper cannot be attained even at the lower concentration, al-

though 1,000 p.p.m. of sludge will cause a removal of about 90 per cent. The greater proportion of the removal of copper is accomplished during the first 10 to 15 min. of contact.

Experimental data show that as the sludge volume index increased, the capacity of the sludge to remove metal decreased. This may indicate that the process involved is not merely one of base exchange, but that the removal of a metal may also be a function of some biological activities, since the predominant organisms in the bulky sludge may be less active in this respect.

The formula HA·BOH has been proposed to account for both the acidoid and basoid natures exhibited by activated sludge (12), HA representing the acidoid with its dissociated hydrogen or other cations. If the dissociated cation is displaced by a less dissociated one, there is a decrease in the hydration and the complex becomes more isoelectric or isoionic (10). Under these conditions the volume occupied by a unit weight of the acidoid should decrease. If, on the other hand, the newly associated cation is more voluminous or more hydrated than the one displaced, then the resulting complex will occupy a greater volume per unit weight.

The atomic volumes (atomic weight/density) of copper and zinc are 7.12 and 9.09 cu. cm. per gram-atom, respectively. These values are very low in comparison to the atomic volumes of the alkali or alkaline earth metals reputedly associated with the sludge zeolite. When copper is the displacing cation, since it is of a lesser volume than the cation displaced, the resultant complex should become more compact. This is exactly the result obtained when the resultant sludge indices, as percentages of the original sludge index, are plotted. These resulting indices are always lower than the original.

If the resultant indices are plotted as a function of the contact time it is evident that 5-min. contact is sufficient to lower the index to the minimum level, after which it remains practically constant despite longer contact. The more copper associated with the activated floc, the lower the resultant index should be. Repeatedly subjecting the same batch of activated sludge to fresh charges of copper results in additional removal of copper during each cycle. There is a simultaneous lowering of the sludge volume index corresponding with the additional association of copper on the activated sludge.

The same general conditions hold true for zinc, but to a lesser extent than for copper. The atomic volume of zinc is only slightly greater than that of copper, and thus the effect it exerts should be very similar. The failure of zinc to depress the sludge index more than it does may be due to the fact that the zinc atom tends to hydrate very readily. This may explain the rise in the sludge index which may occur after contact between activated sludge and zinc.

In any base exchange process involving the use of natural or synthetic zeolites (as, for example, water softening), it is possible to re-use the zeolite several times before it loses its capacity for removal of cations. Experiments to determine whether this is applicable to removal of zinc or copper by activated sludge show that the sludge does possess this quality but to a smaller extent than one would expect of a true zeolite. Results show that of the 15 p.p.m. of zinc added in the first cycle, 5.1 were removed; of the second 15 p.p.m. added, 3.4; and of the third, 2.5 p.p.m. The same general picture is presented if 7.5 p.p.m. of zinc are added per cycle.

The data are more striking for copper. Treating 1,000 p.p.m. of activated sludge with 55 p.p.m. of copper per cycle resulted in the removal of 56 per cent of the copper added during the first cycle, but the second cycle removed only 6.8 per cent of the 55 p.p.m. of copper added, and after the third addition of copper the amount of the metal found in the effluent was 10 p.p.m. greater than the

amount added. Since the sludge was carefully washed between cycles to insure removal of copper-bearing effluent, this additional copper could come only from the sludge. The same trend is evident with a lower concentration of copper and at the higher concentration of activated sludge used. Removals in the latter case with addition of 55 p.p.m. of copper per cycle were 98 per cent during the first cycle, 6.5 per cent during the second, and an increase of copper in the effluent at the end of the third cycle.

In comparison with inorganic zeolites, activated sludge has a very low cation exchange capacity. The fact that after the third cycle the amount of copper found in the effluent was greater than the amount added seems to indicate that no ordinary zeolitic action is involved. After a zeolite has adsorbed as much of a certain cation as its capacity allows, it cannot remove more of that ion from solution, but there is no reason why that ion should be desorbed in the presence of a solution of its salt. While base exchange cannot be ruled out as a possible mechanism, the evidence suggests that some other force also comes into play.

The process involved in zeolitic water softening is illustrated by the general equation

$$2NaZ + Ca^{++} = CaZ_2 + 2Na^{+}$$

After being saturated with calcium ions, the zeolite is regenerated by the reverse reaction and the zeolite regains its exchange capacity for calcium. Treating with a sodium chloride solution activated sludge that has already removed copper should have a similar effect, but experimental evidence shows that activated sludge does not exhibit true zeolitic behavior in this respect. Theriault and McNamee (17) reported that a salt solution of 2 to 4 per cent is sufficient to regenerate the sludge. Sodium chloride solutions of two different concentrations were used in attempting to regenerate the sludge, but neither of these regenerative solutions had the expected effect. There was little difference in the total effect of the two salt solutions, despite the wide divergence in their respective concentrations. Sodium stands fourth and copper seventeenth in the electromotive series of metals. There is no question about the ability of the sodium to replace the copper, provided the activated sludge is capable of giving up the metal once it has adsorbed it, which should be the case if the removal of metals is a strict base exchange reaction involving a zeolite.

Both ripe sludge and fresh solids behave in a manner similar to activated sludge in respect to the removal of copper. These materials remove a progressively increasing amount of the metal up to a certain maximum, at which the removal levels off. The maximum point can be correlated to the removal of copper on the basis of the organic matter present in the biological material.

McGeorge (8) found that the exchange capacity of highly organic soils is a linear function of the percentage of carbon in the soils. The carbon was shown to be organic in nature; hence, the conclusion reached may be revised to read that the exchange capacity is a linear function of the percentage of organic matter. This relationship also holds true for the materials utilized containing masses of biological growths; hence, the kind of organic matter is important. The greatest unit removal was exhibited by the activated sludge, and the organic matter in this material is different from that in ripe sludge and fresh solids.

Theriault has stated that the rapid removal of material occurring during the clarification stage of the activated sludge process is due to an inorganic zeolite found in the sludge matrix. It must be remembered, however, that his conclusions were reached from consideration of data collected after the study of only one biological material, activated sludge. The removals effected

by ripe sludge, fresh solids, or activated sludge, if considered singly and apart from the others, can be related to either the inorganic or organic content of the material. It is only when the removals effected by all three are considered together that it becomes clear that these removals are related only to the organic matter content of the sludges.

The statement has been made by various authors that clarification follows Freundlich's adsorption isotherm,

$$X/M = KC^n.$$

Repeated experiments, using constant concentrations of activated sludge, ripe sludge, or fresh solids and varying concentrations of copper to determine whether removal of copper obeyed the adsorption isotherm, failed to substantiate the claims.

The mass of information obtained indicates that removal is not due to adsorption by surface as such, nor is it due to a base exchange mechanism involving an inorganic zeolite. Removal appears to be the result of two concomitantly acting causes—base exchange between the metal and the organic matter of the biological material, plus biological activity.

Biological purification of sewage is adversely affected when toxic metals, such as copper, are present. Since the metals are readily adsorbed and the capacity of the organic matter to hold the toxic material is relatively high in comparison with the toxic substances found in sewage or industrial wastes, a gradual deterioration of the processes may result, even when a continuous discharge of the toxic material concentration is low. In the case of activated sludge, where the "sludge age" may be several days before it is wasted, the limits of copper concentration allowed would be materially less than those found by batch experiments. Sludge digestion is subject to even greater effects, because the toxic material can accumulate to a greater extent in the fresh solids and ripe sludge kept for rather long periods in the digesters. It is of particular interest that activated sludge may adsorb copper to as much as 4 per cent of its dry weight of organic matter present, and fresh solids about 2.5 per cent.

By the same token, fresh sewage solids, ripe sludge, or activated sludge can be utilized to remove rather large quantities of such toxic metals and prevent their discharge into receiving streams. The use of fresh solids for such a purpose with subsequent disposal of the sludge by incineration or dumping is quite feasible and may be attractive.

Conclusions

The following conclusions have been reached:

1. Toxic metals, such as copper and zinc, are readily removable by activated sludge, ripe sludge, and fresh solids.

2. The extent to which the metal is removed is a function of the concentration of the sludges, the contact time, and the character of the sludge.

3. That an inorganic zeolite is responsible for removal of metals can be ruled out because of the relatively low capacity of the sludges for metals, the desorption of a metal which occurs in the presence of a solution of a salt of that metal, failure of the sludges to respond to regeneration by sodium chloride, and lack of agreement between the unit removals of metal by the inorganic portion of the types of three sludges used.

4. The modifications of the activated sludge volume index occurring after contact between the sludge and a metal show that removal is attendant upon union of the metal with some part of the biological material, probably involving a base exchange mechanism.

5. The agent primarily responsible for removal of metals by activated sludge, ripe sludge, or fresh solids is the organic matter in these materials. Not only is the organic matter itself important, but the type of organic matter has a direct bearing on the amount

of metal removed by a unit quantity of the biological growth.

6. Fresh solids may absorb as much as 2.5 per cent; ripe sludge, 3 per cent; and activated sludge, 4 per cent of metal by weight of the organic matter present.

7. Sludges may be used as agents to remove toxic metals from liquids.

Summary

Extensive studies were made to determine the ability and efficiency of activated sludge, fresh solids, and ripe sludge to remove copper, zinc, and chromium from sewage. Contact time and character of sludge were considered as factors in determining the extent of the removal. Modifications in the sludge volume index caused by the contact with toxic metals and the zeolitic nature of the sludges were studied. The organic matter content of the sludges was found to be responsible for the removal of the metals, but the type and character of the sludges have a direct bearing on the unit amount removal of the metals. Attempts to correlate the removal of copper by the sludges with the adsorption isotherm of Freundlich failed. The absorption capacity of sludges may be utilized for removal of toxic materials from liquids.

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SEWAGE DISPOSAL PROBLEMS IN THE WORLD'S LARGEST CITY *

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The subject of sewage disposal problems in New York City is a broad one. Obviously, it is impossible to discuss all of the problems, or even to list their total number and nature. For the purpose of this paper, therefore, it has been chosen to give some of the background against which these problems arise, indicate in broad terms what is being done, and discuss in greater detail some of the more important developments in design and practice.

For the most part, the problems of sewage disposal in New York City are not different from those in any other city, in that the basic sciences and knowledge of sewage treatment must be invoked. There are, however, certain local conditions and circumstances that have influenced practices and guided the course of development.

The City is composed of five separate boroughs, or counties, and the sewer system in each is controlled by its borough government. These boroughs are mostly separated by major bodies of water. Manhattan and Richmond are islands. The Bronx is separated from the others by the Harlem and East Rivers. Only Queens and Brooklyn are on contiguous land surfaces. The harbor has two outlets; one to the ocean at the Narrows and the other to Long Island Sound through the East River. In addition to large tidal flows, it receives the discharges of the Hudson, Passaic, and Hackensack Rivers.

The pattern of sewage treatment has been largely determined by the distribution of pollution that results from currents set up from these stream and tidal flows. One of the major objectives of the sewage treatment program is to restore and protect the quality of bathing and recreational waters that surround the city. It is found, however, that the ever-increasing standards of purity sought by health authorities and the public are incompatible with the standards established for the control of sewage discharges. Thus it is that at critical locations higher degrees of treatment have been installed than are necessary to meet existing standards or to maintain adequate protection of the inner harbor.

Early Pollution Abatement

At this point, a brief resumé of the status of pollution abatement may be in order. Sewage treatment in New York goes back to 1889, when some of the first chemical treatment plants in the country were started. It was not until 1930, however, that its control was placed on a city-wide basis. At that time, there existed some 9 small plants, mostly of the fine screen type, some of which are still being operated.

Construction of the first modern sewage treatment works started in 1931 at Wards Island. The need for this project lay in intolerable conditions of pollution, and even offense, in the waters of the Harlem and lower East Rivers in the heart of the city. Delayed by the depression, it was placed in operation in 1937. The once blighted sections of the city in this area have since undergone a marvelous transformation, with the construction of marginal drives,

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parks, stadiums, housing developments, schools, and hospitals.

Following Wards Island, emphasis was placed on removing pollution from areas suitable for recreation. First came the plant at Coney Island to protect the famous beach of that name. The first capacity of 35 m.g.d. was increased to 70 m.g.d. in 1941 to eliminate foul conditions in Paerdegat Basin on Jamaica Bay. In 1939, the 40-m.g.d. plants at Tallmans Island and Bowery Bay were operated to clean the waters of Flushing Bay and the adjacent upper East River in anticipation of the World's Fair. Next in order came the small City Island-Harts Island plant on Long Island Sound near the popular Pelham Bay Beach. This was followed in 1943 by the 65-m.g.d. Jamaica plant in Queens, and in 1944 by the first stage of the 60-m.g.d. 26th Ward Plant in Brooklyn, both on Jamaica Bay.

Present Status

Following World War II, with the renewed availability of construction materials, an accelerated program was started in 1949 designed to clean up recreational waters by 1953. Under this program, additional areas were brought to Wards Island by the East Bronx intercepting sewer and to Tallmans Island by the Whitestone intercepting sewer. Secondary treatment started at 26th Ward in March, 1951. In 1952, operation began at the 160-m.g.d. Owls Head plant in Brooklyn, the 120-m.g.d. plant at Hunts Point in the Bronx, and the 15-m.g.d. plant at Rockaway in Queens. The 10-m.g.d. installation at Port Richmond, Staten Island, is well advanced in construction.

Currently, 14 plants are operated (Figure 1), of which 10 are modern and 4 are old screening plants due for replacement. About two-thirds of the city's sewage, estimated at 1,100 m.g.d., is being treated under an annual operating budget of about $4,250,000. The city has spent or appropriated about $144,000,000 on its sewage disposal works. The treatment of all sewage will raise this figure to $317,000,000 at present estimates.

Choice of Location Limited

As intimated previously, local conditions have great influence on the selection of treatment areas, plant sites, and processes. All sewers terminate at tide level, most are combined sewers. Intercepting sewers must be in deep construction along the water front, and in congested areas with many obstructions. These conditions, together with isolation by natural waterways, make necessary a large number of treatment plants. Sites suitable for treatment works are hard to secure. Most good areas have been built up, so recourse must be had to areas of poor foundations and oftentimes to the use of areas covered by water. In all cases, sites are close to habitations, so that the utmost precaution must be made for the control of odors.

This matter of odor control is an important element in the extensive use of sludge digestion and aeration processes. This and area considerations mitigate against the production of fertilizer at the plant site. Fortunately, the waterfront locations and excellent waterways permit the ready disposal at sea of most of the sludges. This operation, now carried out by four ocean-going sludge vessels, one new in 1952, has proved most successful and economical. In 1951, direct operating costs for sludge disposal for four activated sludge plants amounted to only $2.97 per m.g. No comparable figure is known for this type of plant, except where large isolated areas are available.

Gas Utilization

Use of sludge digestion for odor control and the inoffensive storage of sludge between sea shipments has the further advantage of yielding the useful by-product, methane. This gas has been used in most of the newer

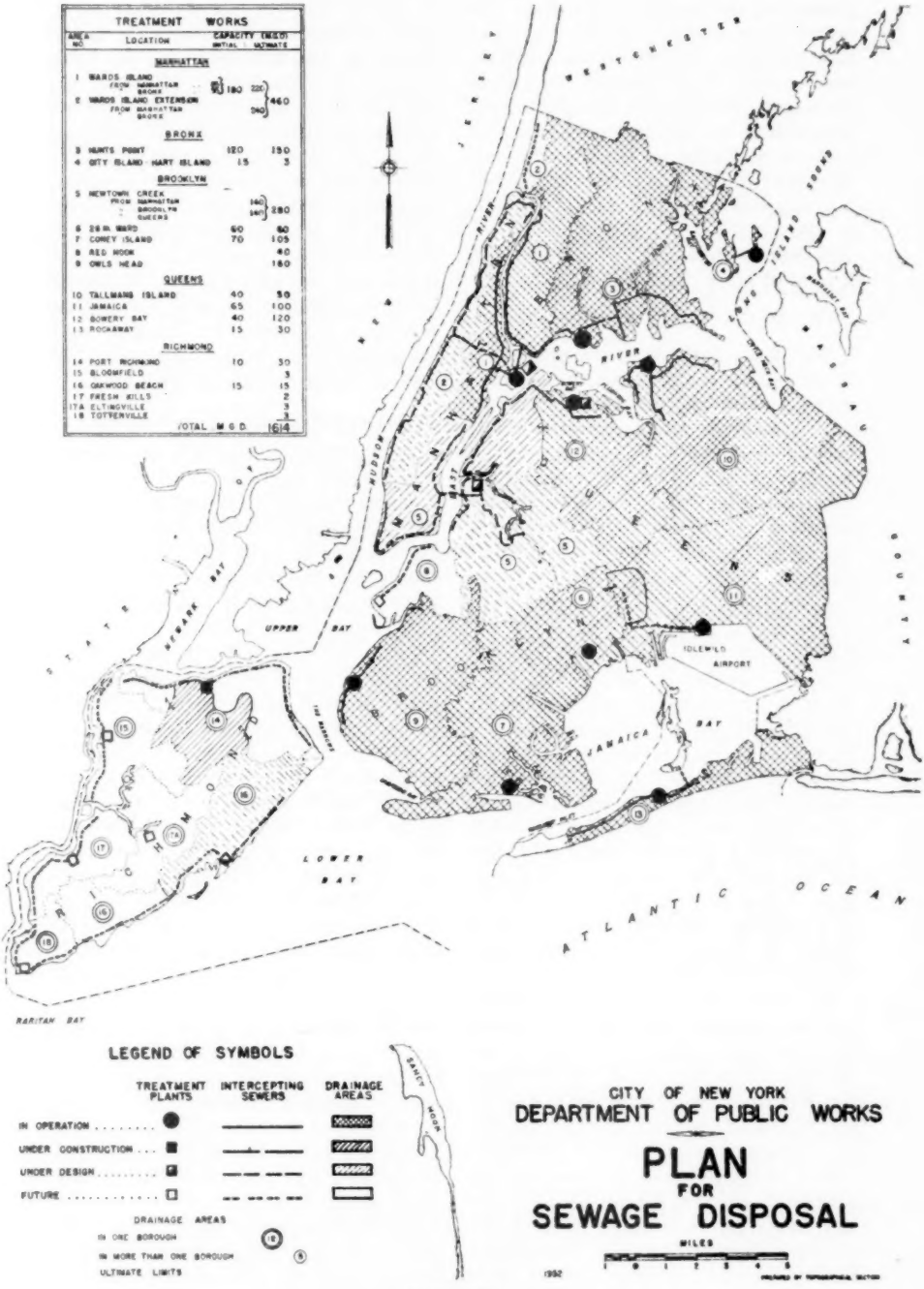
TREATMENT WORKS
AREA NO. LOCATION CAPACITY (M.G.D.) INITIAL ULTIMATE
MANHATTAN
1 WARDS ISLAND FROM MANHATTAN FROM BRONX 180 220
2 WARDS ISLAND EXTENSION FROM MANHATTAN FROM BRONX 240 460
BRONX
3 HUNTS POINT 120 150
4 CITY ISLAND - HART ISLAND 15 3
BROOKLYN
5 NEWTOWN CREEK FROM MANHATTAN 140 FROM BROOKLYN 140 280
6 26th WARD 60 60
7 CONEY ISLAND 70 105
8 RED HOOK 40
9 OWLS HEAD 160
QUEENS
10 TALLMANS ISLAND 40 50
11 JAMAICA 65 100
12 BOWERY BAY 40 120
13 ROCKAWAY 15 30
RICHMOND
14 PORT RICHMOND 10 30
15 BLOOMFIELD 3
16 OAKWOOD BEACH 15 15
17 FRESH KILLS 2
17A ELTINGVILLE 3
18 TOTTENVILLE 2
TOTAL M.G.D. 1614
WESTCHESTER
HUDSON RIVER
EAST RIVER
LONG ISLAND SOUND
NEWARK BAY
UPPER BAY
KILL VAN KULL
IDLEWILD AIRPORT
JAMAICA BAY
LOWER BAY
ATLANTIC OCEAN
RARITAN BAY
SANDY HOOK
LEGEND OF SYMBOLS
TREATMENT PLANTS
INTERCEPTING SEWERS
DRAINAGE AREAS
IN OPERATION
UNDER CONSTRUCTION
UNDER DESIGN
FUTURE
DRAINAGE AREAS
IN ONE BOROUGH
IN MORE THAN ONE BOROUGH
ULTIMATE LIMITS
CITY OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
PLAN
FOR
SEWAGE DISPOSAL
MILES
1952

FIGURE 1.

plants to generate power and heat. As power rates continue to rise, production of power becomes more advantageous. This is particularly true since the development of the dual-fuel diesel engine that was first pioneered in this country at Tallmans Island. Practice in this field has grown from three 300-h.p. engines at Coney Island in 1935 to six 1,300-h.p. units at Owls Head. Altogether there are 35 engines with a total of more than 29,000 h.p.

Activated Sludge Modifications

The desire for substantial degrees of treatment in compact plants on small areas has led to two modifications of the activated sludge process that greatly reduce the required size of aeration tanks. These processes are "step aeration" and "modified sewage aeration." The latter is sometimes known as "high-rate activated sludge." Both of these processes are based on the concept that the quality and characteristics of activated sludge are determined by the "sludge age" or period of circulation under air. The stage of desired biological development is a function of time and temperature. In step aeration it is sought to produce the quality product of full activated sludge, but in a smaller aeration tank. In modified sewage aeration it is sought to produce a workable result with low air use, heavy excess solids, with perhaps a less perfect effluent, and also in a smaller aeration tank; in other words, an economical process of intermediate purification.

In most activated sludge plants treating normal sewages it is found that the total weight of sludge in the aeration tanks must be 3.5 to 4.0 times the weight of the suspended solids of the incoming sewage. In other words, the flowing-through time or detention period of the sewage solids undergoing biological action is 3.5 to 4.0 days. In step aeration this same weight of sludge is circulated within the system, but by diluting the return sludge with sewage at several different points as it passes through the aeration tank, much heavier concentrations are maintained in the first part of the tank than at the effluent end. Parallel operations have shown that the over-all results are identical with the conventional activated sludge methods and that usually only one-half the aeration tank capacity is required. The ability to vary the amounts and points of sewage inlet is an essential and a most convenient and useful tool in the hands of an experienced operator in meeting changing conditions of loading and maintaining the sludge quality. The step aeration process is patented.

Activated Sludge Developments

It is fitting to digress a moment at this point to pay tribute to those who pioneered many years ago in developing the activated sludge process. They did not happen upon the "sludge age" theory but were conscious that under some circumstances it was desirable to precondition return sludge prior to its aeration with sewage. Thus, in England with its stronger sewages and at places in this country was found the rather common practice of sludge reaeration. As practice developed in this country with weaker sewages, the custom was to eliminate the reaeration phase rather than to shorten the subsequent aeration period. Step aeration in reality follows the earlier pattern of sludge reaeration under heavier concentrations, but with an abbreviated contact with the sewage. The vital exception is that the reaeration period and the aeration period with sewage can be adjusted to meet fluctuating conditions of loading. Reaeration, followed by an abbreviated aeration period with sewage, without the controls necessary for making adjustments for variations in loading, may result in an unworkable process. The efficient use of air is also involved.

Modified aeration as developed in New York is identical in flow plan to conventional activated sludge—no step gates are provided. The essential dif-

TABLE I.—Major Elements of New York City Activated Sludge Plants

Plant	Design Capacity (m.g.d.)	Placed in Operation	Detention Period (hr.)			Final Tanks Overflow (g.p.d./sq.ft.)	Designed for
			Primary Tanks[1]	Aeration Tanks	Final Tanks[1]		
Wards Island	180	1937	1.23	6.58[2]	3.08	742	Conventional act. sl.
	240	1949	0.92	4.20[2]	2.31	990	Step aeration[4]
Tallmans Island	40	1939	1.00	3.36[2]	2.61	792	Step aeration
Bowery Bay	40	1941	1.00	2.42[2]	2.14	996	Step aeration[4]
Jamaica	65	1943	None	2.44[2]	3.02	720	Step aeration[4]
26th Ward	60	1951	1.51	3.32[2]	2.24	975	Step aeration[4]
Hunts Point	120	1952	1.25	3.00[2]	2.50	1,000	Step aeration
Owls Head	160	1952	None	1.9[3]	1.7	1,280	Modified aeration
Rockaway	15	1952	None	2.0[3]	2.0	1,150	Modified aeration

[1] At 100 per cent flow.
[2] At 125 per cent flow.
[3] At 110 per cent flow.
[4] Provisions made for optional use of modified aeration.

ference between it and step aeration or conventional activated sludge is that it utilizes activated sludge in its initial stage of development. Instead of being held under air for a period of 3½ to 4 days, as in the case of the complete processes, it must not be held longer than about one-tenth of that period. Actually, it is found that with normal sewages the range for modified aeration may be from 0.4 day in cold weather to 0.2 day in hot weather. This requires an exact control to maintain the sludge in the early stage of its biological development where sufficient organisms are present to clarify the sewage and absorb impurities, but not to allow action to progress to the extent that settling quality is affected. In practice this is determined rather simply by settling tests.

The major elements of the activated sludge plants in New York City are given in Table I.

Process Results

General results secured with average sewages are 80 to 85 per cent removal of suspended solids and 75 to 80 per cent removal of B.O.D. Apparently, only about 50 per cent of the portion of the B.O.D. that is soluble is removed, so if excessive quantities of soluble B.O.D. are present, lesser overall removals can be expected. Sludge can be concentrated to from 5 to 8 per cent solids, depending on the presence of primary tanks. For this reason, although the return of sludge to the aeration tank is essential to the process, the volume of return sludge is small. It need only be about 5 per cent of the sewage flow. Excellent results have been secured with aeration periods as low as 1.5 to 2.0 hr. In order to maintain the proper "age" relationship, the actual concentration of solids in the aeration tank will vary inversely with the aeration period and directly with the strength of the applied sewage. Preliminary settling tanks appear to be of little advantage. Three of the plants using this process have preliminary settling tanks, three others do not.

Plant Modifications

At three of the plants originally designed for step aeration minor modifications have been made so that modified aeration can be used. With their abbreviated aeration tanks they are quite suitable for the modified process. This permits optional or seasonal use of either process. At Wards Island, originally designed for conventional activated sludge, step aeration gates

have been provided and also controls that permit the use of modified aeration. The four separate batteries here have been used for extended periods for the parallel operation of conventional activated sludge, step aeration, and modified aeration. Modified aeration requires about one-half of the air necessary for conventional activated sludge or step aeration.

With either of the systems of activated sludge that are being used, there has been a realization of the importance of returning activated sludge from the final tanks in as fresh a condition as possible. To this end the final tanks have been modified to take advantage of the density currents formed by the voluminous sludge. The points of sludge withdrawal are placed sufficiently far from the inlet end so that the flowing sludge will have concentrated to the volume of the return sludge pumpage and be removed in the space of one-half hour or so.

Chloride Content Problems

Another troublesome problem in connection with density currents is probably confined to tidewater cities. Here practically all combined sewers discharge below high tide level and it is necessary to keep out salt water by means of tide gates. There is always some leakage owing to the hanging up of material on tide gate seats. The leakage varies with the stage of the tide, so that there is fluctuation of chloride concentration. This is oftentimes sufficient to cause the sewage in the final tanks to stream either along the top surface or along the bottom of the tank, depending upon the relative chloride contents of the tank and the sewage. These currents may travel at a rate up to 10 ft. per min. For this reason, as long a course of travel as possible is provided so that sediment in this fast-flowing current will have time to settle out. This is accomplished by using long straight-line tanks or splitting tanks by baffles so that there will be a U-shaped flow pattern. Most of the older tanks have been altered to conform to these principles, with marked improvement in results, and of course these ideas have been followed in the newer designs.

Other Problems

Immediate problems of a technical nature have to do with further improving the sludge concentration and digestion practices. It is too early to report on these matters as the work has chiefly been limited to one location. Suffice it to say that for a period of 9 months mixtures of primary and "modified" sludge have been concentrated, generally to from 9 to 14 per cent solids. As to digestion, it is indicated that present capacities can be substantially reduced. Also, there appears to be little advantage for local purposes in long-term secondary digestion.

The scope of this paper does not permit coverage of many other problems of perhaps equal interest. Treatment of matters such as tide gates, sewage regulators, screens, grit chambers, mechanical and electrical equipment, digestion practice, air diffusion, and many others in which New York City forces have reached their own solutions, would appeal to some. Others would be interested in the ups and downs of the city's financial picture, to say nothing of the administrative and personnel matters under the terms of office of five mayors and ten commissioners.

EFFECT OF TEMPERATURE ON SEWAGE TREATMENT PROCESSES

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Notation

In this paper the following nomenclature is used throughout:

- c = a number chosen to fit experimental data (often assumed to be 1.047 in laboratory B.O.D. calculations when transferring results from one temperature to another);
- f = the fraction of B.O.D. remaining in the effluent;
- K = the B.O.D. reaction coefficient, in natural logarithms;
- k = the B.O.D. reaction coefficient, in common logarithms; k_T = at any temperature T, in 1/days; k_{20} = at the standard temperature (20° C.), in 1/days;
- L = ultimate first-stage B.O.D. remaining at time t; L_a = at $t = 0$;
- M = a substitution factor, $= c^{(T-20)}$, used to simplify the typography of Eqs. 4 and 5;
- N = a substitution factor, $= \frac{1}{T_2 - T_1}$, used to simplify the typography of Eqs. 7 and 8;
- p = the fraction of B.O.D. removed, $= 1 - f$;
- R = a substitution factor, $= c^{(T_2 - T_2)}$, used to simplify the typography of Eqs. 9 and 10;
- S = the slope of a plotted line (see Table I);
- T = temperature, in ° C.;
- t = time, in days;
- θ = temperature, in ° F.; and
- $\Delta\theta$ = the temperature interval, in ° F.

Subscripts 1 and 2 used with the foregoing nomenclature denote quantities determined for run 1 and run 2, respectively, in a given plant.

Basic Considerations

A plausible theory (4)(5) to explain the effect of temperature upon biological oxidation processes of sewage treatment is that which relates the reaction coefficient K (or k, $= 0.4343K$) to temperature in the form:

$$k_T = k_{20}\, c^{(T-20)} \qquad (1)$$

The value of k_T appearing in Eq. 1 is used in:

$$L = L_a\, 10^{-k_T t} \qquad (2)$$

It should be noted that in this form L or L_a may be in any units, as long as both are the same. In fact, both could be in terms of 5-day B.O.D., rather than first-stage B.O.D.

The fraction, f, of B.O.D. remaining in the effluent after time t has elapsed in an oxidation process, such as occurs in a trickling filter, is given by

$$f = \frac{L}{L_a} = 10^{-k_T t} \qquad (3)$$

Combining Eqs. 3 and 1 gives

$$f = 10^{-t\, k_{20}\, M} \qquad (4)$$

But p, the fraction removed, is equal to $1 - f$. Therefore,

$$p = 1 - 10^{-t\, k_{20}\, M} \qquad (5)$$

An attempt is made in this paper to show that the effect of temperature upon oxidation processes, as shown by Eqs. 4 or 5, gives results in good agreement with certain operation data and that nearly the same values of c give fair agreement with available opera-

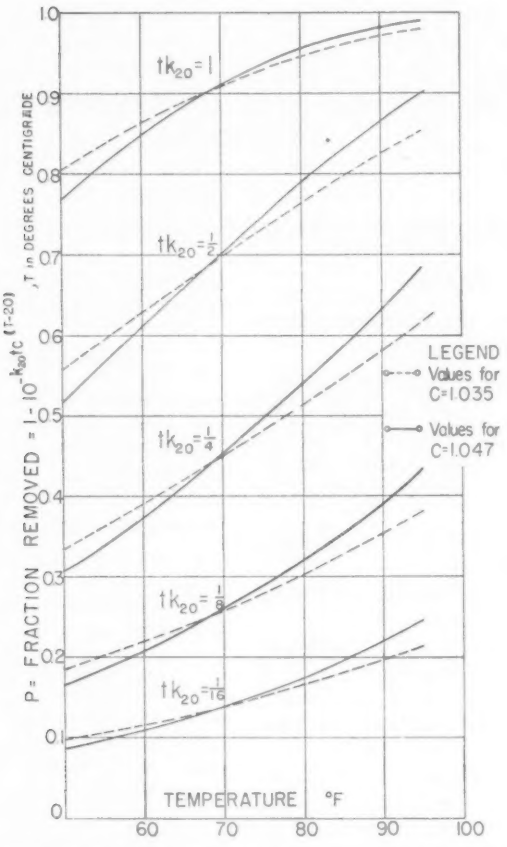

FIGURE 1.—Theoretical effects of temperature upon removal of organic matter.

tional data from both high-rate filters and activated sludge plants. Observed lack of agreement (that is, variations of values of c) is considered later.

Short-Comings of Slope Method

To show such agreement it is first necessary to display the inherent short-comings of certain other methods employed in the literature for representing the effect of temperature upon sewage treatment processes; in particular, the slope of the fractional removal *versus* temperature lines—the p vs. T lines (Figure 1).

According to the theory previously presented, the effect of temperature upon fractional removals from Eq. 5 is shown in Figure 1, where p is plotted vertically and temperature in degrees Fahrenheit is plotted horizontally. Two values of c have been chosen for this plotting. The value of 1.047 is standard for B.O.D. bottle calculations; 1.035 is a value that fits well certain plant results reviewed in this study (Figure 2).

The several curves indicate the relation between removal and temperature for various particular constant values of the product $t\ k_{20}$, as shown. The large values of the product $t\ k_{20}$ represent plants that give high removals because of long effective times of contact between sludge or slime and sewage, and/or because of superior effectiveness

of the slime or sludge, or possibly because of a light organic load. The lowest lines, for low values of $t\,k_{20}$, more nearly represent the action of scrubbing filters. (The product $t\,k_{20}$ is dimensionless.)

From a study of the full lines in Figure 1, where c is a constant and equal to 1.047, it is evident that the slope of the lines or the numerical increase in fractional removal occurring in a particular interval of temperature change—say from 70° to 80° F.—is less at high and at low values of the product $t\,k_{20}$—say where $t\,k_{20} = 1.0$ and $t\,k_{20} = 1/16$—than at intermediate values—say where $t\,k_{20} = 1/4$. Furthermore, the numerical change of p along a particular line is different for one interval of temperature—say from 50° to 60° F.—than for another of the same magnitude—say from 80° to 90° F. Thus, from this theory it would seem that the slope of such lines as these is a highly variable quantity; its magnitude is, by itself, a disturbingly elastic measuring stick to determine the temperature effects.

(Figure 1 also shows that as c is decreased, the slopes of all corresponding portions of all corresponding lines diminish; that is, comparable temperature effects decrease as c decreases.)

Another more obvious way of presenting the objection to slope of the

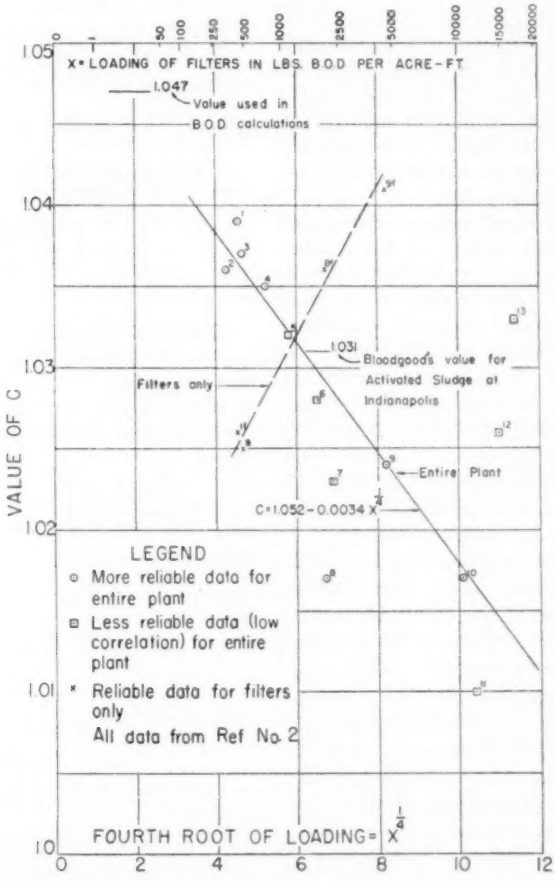
X = LOADING OF FILTERS IN LBS. B.O.D PER ACRE-FT
1.047
Value used in B.O.D calculations
1.031
Bloodgood's value for Activated Sludge at Indianapolis
Filters only
Entire Plant
C=1.052-0.0034 X^1/4
VALUE OF C
FOURTH ROOT OF LOADING = X^1/4
LEGEND
More reliable data for entire plant
Less reliable data (low correlation) for entire plant
Reliable data for filters only
All data from Ref No. 2

FIGURE 2.—Relation between organic loading and temperature effect as measured by c.

p vs. T lines as a comparable measure of temperature effect is to compare two imaginary lines of equal slope; one in which the increase in p as temperature goes from 50° to 60° is from 0.50 to 0.60, the other in which the increase in p as temperature goes from 50° to 60° is from 0.10 to 0.20. In the first case the pounds of B.O.D. removed is increased by (10/50) 100 = 20 per cent. In the second, the pounds of B.O.D. removed is increased by (10/10) 100 = 100 per cent. Common sense would indicate the temperature effect to be more significant in the second case than in the first; yet the slopes of the corresponding portions of the p vs. T lines are the same.

Besides the inherent theoretical effects of temperature upon the fractional removal of B.O.D. by oxidation, as exemplified by Figure 1, there are doubtless also others peculiar to the type or concentration of wastes, the peculiarities of plant design and of mode of operation, or other factors.

(The adsorption, sedimentation, and oxygen solubility effects of temperature upon removal are considered later in this paper.) The influences of such additional factors upon the combined temperature effect cannot readily be distinguished by means of the highly varying slope of the p vs. T lines unless comparisons are made between corresponding portions of corresponding lines, and it is very difficult to find such corresponding portions of corresponding lines to make the comparisons.

For all these reasons, it seems preferable to compute from experimental data the value of c as the fundamental measure of the effect of temperature upon the phenomenon. When c is relatively large, the effect of temperature is judged to be relatively large and presumably would prove to be relatively large when the slopes of corresponding portions of corresponding p vs. T lines were properly compared, as shown by comparing the full and dotted lines of Figure 1.

Calculation of c

Accordingly, formulas have been derived to facilitate the calculation of c to make such comparison possible; also, when the values of c are known, to determine the change in p as the temperature changes by known amounts.

From Eq. 4 it is evident that

$$\log (1/f_1) = t_1 k_{20} c^{(T_1-20)} \qquad (6a)$$

and

$$\log (1/f_2) = t_2 k_{20} c^{(T_2-20)} \qquad (6b)$$

Solving Eqs. 6 for c, it follows that

$$c = \left[\frac{t_1 \log 1/f_2}{t_2 \log 1/f_1}\right]^N = \left[\frac{t_1 \log f_2}{t_2 \log f_1}\right]^N \qquad (7)$$

Example A—

When

$$f_1 = \frac{20}{196} = 0.102, \quad f_2 = \frac{20}{182} = 0.110,$$

$T_2 - T_1 = 12$, $t_1 = 11.3$, and $t_2 = 7.8$,

$$c = \left[\frac{11.3}{7.8}\frac{\log 0.110}{\log 0.102}\right]^{1/12}$$

$$= \left[1.45\left(\frac{-0.958}{-0.991}\right)\right]^{1/12}$$

$$= (1.40)^{1/12} = 1.028$$

This and Example C are from the article by Bloodgood (1) and are referred to later.

When $t_1 = t_2$, as when volume rates of treatment are the same in a given plant,

$$c = \left[\frac{\log 1/f_2}{\log 1/f_1}\right]^N = \left[\frac{\log f_2}{\log f_1}\right]^N \qquad (8)$$

Example B—

When $f_1 = 0.315$, $f_2 = 0.196$, and $T_2 - T_1 = 8.91$, $c = 1.039$, as shown in the first line of Table I.

Example C—

When $f_1 = f_2$, from Eq. 7

$$c = \left[\frac{t_1}{t_2}\right]^N \qquad (9)$$

For the values $t_1/t_2 = 1.45$ and $T_2 - T_1 = 12$,

$$c = 1.031$$

Fortunately, the literature provides experimental data which enable the calculations of c to be made for both activated sludge and for trickling filter plants so as to determine the effect of temperature upon the purification process in these plants.

For the first example reference (1) is cited. Here a curve is given that shows the relation between detention time and temperature for what is called "optimum operation." The loading of the plant was kept as high as possible at all times for satisfactory operation. On the assumption that this meant constant fractional removals, and using the values obtained from the extremities of the curve, a value of $c = 1.031$ was obtained as computed in Example C, above. On the assumption that "optimum operation" meant constant concentration of 20 p.p.m. B.O.D. in the effluent and using the average B.O.D.'s of the three nearest points at each extremity of the line, a value of $c = 1.028$ was obtained as shown in Example A, above. Bloodgood believes the first assumption to be closer to the truth than the second; consequently, c is probably closer to 1.031 than 1.028. (Compare this value with the value of 1.032 obtained for the average of the data from four trickling filters presented hereinafter. Compare it also with the value of $c = 1.047$ often used in B.O.D. bottle test calculations.)

The next example comes from a recent article by Schroepfer and associates (2). The authors presented their results very completely and have determined the average slopes of pT lines of best fit, together with correlation coefficients for 13 sets of data of "total" plant operation and for four sets of data of operation of "filters only" for trickling filter sewage treatment plants. From these carefully plotted lines the values of f_1 have been read off at the left extremity of the lines, as plotted in the original article (2), and the values of f_2 have been calculated at the right hand extremity of the lines for given

TABLE I.—Calculation of Value of c

Line No.*	Correlation Coefficient	Median Load (lb. B.O.D./ acre-ft.)	$\sqrt[4]{\text{Load}}$	f_1	100 S†	$\Delta\theta$‡	$S\Delta\theta$	f_2	c§
1	0.75	425	4.51	0.315	0.740	16	0.119	0.196	1.039
2	0.79	325	4.25	0.330	0.680	24	0.163	0.167	1.036
3	0.66	475	4.64	0.300	0.673	20	0.135	0.165	1.037
4	0.80	750	5.22	0.360	0.669	24	0.161	0.199	1.035
5	0.41	1,250	5.80	0.300	0.601	16	0.096	0.204	1.032
6	0.19	1,750	6.50	0.450	0.552	12	0.066	0.384	1.028
7	0.20	2,280	6.90	0.550	0.423	12	0.051	0.499	1.023
8	0.84	2,015	6.70	0.365	0.337	16	0.054	0.311	1.017
9	0.67	4,630	8.20	0.480	0.474	16	0.076	0.404	1.024
10	0.57	10,500	10.1	0.610	0.301	20	0.060	0.550	1.017
11	0.23	12,500	10.4	0.620	0.181	12	0.022	0.598	1.010
12	0.24	14,500	11.0	0.710	0.304	12	0.0365	0.6635	1.026
13	0.45	16,500	11.4	0.750	0.421	12	0.050	0.700	1.033
1f	0.54	425	4.51	0.400	0.520	19	0.099	0.301	1.026
8f	0.54	2,015	6.70	0.630	0.695	16	0.101	0.529	1.036
9f	0.77	4,630	8.20	0.650	0.690	16	0.111	0.539	1.041
B	0.74	478	4.66	0.250	0.437	20	0.087	0.163	1.025

* Lines 1 to 13, inclusive, are results for entire plant operation; 1f, 8f, and 9f represent same plants and loadings as 1, 8, and 9, respectively, but give results for filter operation only; 1 to 7 represent plants intermittently dosed; 8 to 13 represent plants continuously dosed.

† S is slope of plotted line.

‡ $\Delta\theta$ is temperature interval in ° F.

§ By Eq. 8.

slope and indicated temperature interval. Then, as shown in Example B and with the aid of the values given in Table I, the values of c given in the right-hand column of Table I were calculated. Data are plotted in Figure 2.

It is found that the average values for the "filters only" give a value of $c = 1.032$, ranging from 1.025 to 1.041, increasing as the B.O.D. loading increases and decreasing as the fractional removal increases.

The average value for the intermittently dosed low-rate filter plants is 1.033, ranging from 1.023 to 1.039, decreasing as the B.O.D. loading increases and increasing as the fractional removal increases. Taking out of this group the two points whose data show the lowest correlation coefficients, the average of the five remaining points is 1.036, and the range diminishes (1.032 to 1.039).

Temperature Effects upon Plants Lightly Loaded

From all these considerations, it is concluded that the effect of temperature on lightly or moderately loaded activated sludge plants and trickling filter plants may be very nearly the same, as proved by a substantially constant value of $c = 1.035 \pm 0.006$; therefore, that the effect of temperature upon fractional removals in a plant may be estimated by

$$f_2 = f_1^R \qquad (10)$$

and

$$p_2 = 1 - (1 - p_1)^R \qquad (11)$$

where $c = 1.035$ and $t_1 = t_2$. The calculations involving these formulas, although simple, are facilitated by the use of a log–log slide rule.

However, even these calculations may be avoided by the use of Figure 1. For example, if it is known that $p_1 = 0.39$ at 60° F. and it is desired to find the value of p_2 at 80° F., find a point on the diagram where $p_1 = 0.39$ and temperature is 60° F., then move along a dotted curve (or parallel to a dotted curve) to where the temperature is 80° F. and here read p_2. In this case, $p_2 = 0.515$, which checks the value by Eq. 11, as follows:

$$p_2 = 1 - 0.61^R = 0.515;$$
$$R = 1.035^{5/9(80-60)} = 1.469.$$

From Figure 2, where the results of these studies are summarized, certain other more tentative conclusions may be drawn.

With Schroepfer and associates (2), although for somewhat different reasons, it is concluded that there is an indication of decreasing temperature effects as the loading increases on the purification process of the total plant—although not for the filtration process itself. In fact, there is indication of increasing temperature effects as the filter loadings increase, on filtration removal only (Figure 2).

The lines drawn in Figure 2, and the corresponding equations, are intended as no more than suggestions of possible trend. They are not lines of best statistical fit; yet the radical difference in the apparent trends of the relation for "filters only" and for the entire plant may call for some comment.

To explain the observed relation between fractional removal and plant loading for the entire plant, the following three explanations, all of which may be at least partly applicable, are offered:

1. Oxidation in Settling Tank

In plants with low rates of organic loading the effluent from the filter may contain enough dissolved oxygen at all temperatures to continue the oxidation to a measurable amount in the sedimentation tank, but not the effluents from filters heavily loaded. There is less oxygen dissolved at high temperatures than at low temperatures and of course, a higher rate of oxygen demand; consequently, there is less oxygen remaining in the filter effluent and the oxidation taking place in the sedimentation tank at high loads may actually be diminished by elevating the tem-

peratures. This decreased oxidation in the sedimentation tank would show up as a somewhat lessened improvement of the total plant removal with temperature rise, and as a correspondingly lower value of c at these higher loads, somewhat as was actually observed.

2. Sedimentation

Of course, it is possible that secondary sedimentation tanks are usually so adequately designed as to remove a substantial amount of whatever settleable matter may come to them; therefore, that an increase in temperature could not materially affect their efficiency of removal of this material.

Insofar as this assumption holds, the effect of temperature upon sedimentation could not account for observed decrease in value of c with increased loads on the plant. Such improvement as might occur in the removals of sedimentation tanks with temperature rise would be due entirely to the increase of settleable matter entering from the filter, an effect difficult to estimate.

In general, a rise in temperature should increase the percentage removals by sedimentation because of decreased viscosities and increased velocities of settling. Assuming that settling tank capacities are not unlimited and that percentage removal increases in proportion to increased velocity of settling, it can be shown that raising the temperature from 70° to 80° F. increases percentage removals by about 13 per cent. As shown by Schroepfer (3), the actual removals in sewage settling tanks have so improved in this temperature range by this amount.

Values of c due to the effect of sedimentation alone—not oxidation—in removing B.O.D. have been calculated by Eq. 8. On the assumption that a 13 per cent improvement in removals accompanies a 10° F. temperature rise, it is found that if $p_1 = 0.700$, then $p_2 = 0.791$ and $c = 1.049$. This would represent a light loading of plant with high removals. If $p_1 = 0.522$, then $p_2 = 0.590$ and $c = 1.035$ (same as for oxidation). This would represent a moderate loading of plant with moderate removals. And if $p_1 = 0.300$, then $p_2 = 0.339$ and $c = 1.028$. This would represent a heavy loading of plant with low removals. Thus, it is clear that the effect of increased plant loading upon the sedimentation alone is to decrease the calculated value of c.

It is not so clear what the effect of increased plant loading upon the value of c would be when temperature effects upon sedimentation are combined with temperature effects upon oxidation. Surely the influence upon the value of c would be less than if the effect of oxidation upon temperature were not considered.

It is believed that the influence of temperature upon sedimentation, as considered in this section, is not sufficiently different from the effect of temperature upon oxidation to explain the magnitude of the observed decrease in value of c with increasing loads.

It is remarkable that the apparent effects of temperature rise upon removal by sedimentation and by oxidation are so nearly the same. Surely the mechanisms of the effects are widely different.

3. Adsorption by Floating Solids

The effect of temperature upon the adsorption of dissolved material by the sediment about to be deposited also may help to explain the observed phenomenon. Adsorption is reduced by rising temperatures. If there is relatively more of this kind of removal of organic matter going on at high loads than at low loads, for the reason that there is both a great deal more adsorbent, as well as much more material to be adsorbed, then this harmful effect of rising temperature upon removal in the sedimentation tank would be more pronounced at high loads than at low. This seems to be the case.

If, as is likely, a larger fraction of the total removal is accomplished by sedimentation at the higher, than at the lower loadings, then the effect just

mentioned would be even more noticeable.

Data presented (2) for the more heavily loaded Fort Jackson plant (points 8 and 9 in Figure 4, p. 713) show that removals in the sedimentation tank alone are decreased by increased temperatures, whereas at the lightly loaded Akron plant (point 1 in Figure 2, p. 711) removals in the sedimentation tank are improved at the elevated temperatures. Furthermore, greater proportional removals occur in the sedimentation tanks of the more heavily loaded Fort Jackson plant. These facts strongly confirm one or more of the previous explanations. (Yet, unfortunately, for complete consistency of these theories, the increase of loading in the Fort Jackson plant did not increase the proportion of removal accomplished by sedimentation in that plant.) The long period of detention in the Fort Jackson settling tank (3 hr.) points to the theory of deaeration for the reduced temperature effect in the plant as a whole ($c = 1.024$ and $c = 1.017$), as compared with the greater temperature effects on these filters ($c = 1.036$ and 1.041). These are the only plants of reference (2) where distinctions of operation between the "filters only" and "entire plant" can be made.

Temperature Effect upon Adsorption by Fixed Slime on Filter Stones

Only one explanation is advanced for the observed reverse influence of increasing load upon the temperature effect for "filters only" (Figure 2). Here it is necessary to fix attention upon the adsorption of dissolved material from the sewage by the slime covering the stone of the filters and the oxidation of organic matter taking place in the "filter only." The adsorption of dissolved matter by the suspended matter passing through the filter would still be measured as B.O.D. in filter effluent and would not count as improvement taking place in the filter.

Adsorption of dissolved matter by the slime would probably not be greatly increased by increasing loads upon the filter for two reasons: (a) the adsorbent, the slime, would not increase in exposed surface with increasing loads; and (b) the amount of material adsorbed is not greatly increased by the amount of such material present, according to Freundlich's equation. Consequently the relative effect of adsorption probably decreases with increase in load (i.e., relative to that of oxidation, which theoretically increases in proportion to the amount of oxidizable matter present.) This may be the main reason for the known decreasing fractional removals of filters with increasing loads.

At any rate, it seems reasonable to suppose that the relative importance of adsorption by slime in the filter decreases with increasing loads on the filter. It must be recalled that increasing the temperature reduces the removal by adsorption. Therefore, at light filter loads, when adsorption is relatively important, increasing the temperature reduces an important removal influence. The fractional total improvement in removal from temperature rise is less than it would be if adsorption were not present. On the other hand, at heavy filter loadings, when adsorption is relatively unimportant, an increase in temperature causes only an improvement in removal, due to oxidation, and there is practically no influence of reduced adsorption. This may explain the observed increase in values of c with increasing filter loadings when the results of filters only are under study.

Conclusion

In estimating the effect of temperature upon the purification taking place in heavily loaded plants with the evidence of reference (2) as shown on Figure 2 and as previously explained, a value of c somewhat less than 1.035 is indicated for use in Eqs. 10 and 11. The value of c should be chosen some-

what in accordance with the lines or values of Figure 2. When the time of detention in the sedimentation tank is long, a definite reduction in the value of c is indicated.

It is hoped that the attempt made in this paper to generalize and to explain what appear to be carefully computed and highly reliable plant operation results, from the references cited, will not only throw light upon temperature effects, but also will add some pale illumination to the several purification processes themselves, to indicate their presence and even their relative importance.

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SOUTH CAROLINA CORRESPONDENCE COURSES

The status of correspondence courses for water and sewage works operators in South Carolina is interestingly told in the following excerpts from a progress report published in the Nov.-Dec. issue of *Out of the Spigot*, newsletter of the South Carolina Water and Sewage Works Association:

"On October 16, 1952, applications were received for the first correspondence courses for water and sewage works operators ever offered by an institution of higher learning in South Carolina. Clemson College, through its Engineering Experiment Station, with Professor H. E. Glenn as Vice Director, has undertaken the task of preparing and distributing correspondence courses designed to provide the type of instruction to the water and sewage plant operators, the need for which has long been felt by our group.

"The legislature has seen fit to provide funds for this undertaking; and to point out the wisdom of this movement, we have only to say that Clemson College is now supplying to the water and sewage men in South Carolina 249 courses. In addition to those in South Carolina, 8 courses are being supplied to members who do not live in South Carolina. Numerous inquiries have been received by the Secretary from people from other states who wish to participate in this undertaking. At present the courses are available only to those persons who are members of the South Carolina Water and Sewage Works Association. . . . After one and one-half months of operation, applications have been received from 63 per cent of the counties in the state. . . . In these counties there are 184 men who realize the opportunity offered through the correspondence work in both water and sewage operation and are taking advantage of it. Ninety men are taking work in water treatment only, 73 are taking work in both water and sewage treatment, and 21 are working on sewage treatment only. Included in the 184 men participating are: municipal water and sewage operators, industrial water and sewage plant personnel, water and sewage operators at military installations in South Carolina, industrial representatives and agents, and State Board of Health personnel."

Industrial Wastes

OPERATING AND ECONOMIC FACTORS INVOLVED IN THE STUDY OF A PACKINGHOUSE WASTE PROBLEM *

By H. O. Halvorson

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Whenever it is necessary to install treatment facilities for industrial waste, it is best to proceed first with a more or less detailed study of the waste within the plant. Such preliminary work may reveal ways and means of recovering profitable materials from some of the waste and ways of eliminating others by modifications in plant operations. Time spent on such preliminary studies will inevitably bring about a substantial saving in the cost of the treatment facilities.

During the past few years, the author has been privileged to participate in such a study. Because the techniques used and the results obtained are of general interest, it is felt that that they warrant presentation.

Study Plant

The study was made at the Morrell packing plant at Ottumwa, Iowa. The plant slaughters hogs, cattle, and sheep with a plant capacity of about 2,000,000 lb. of live animal slaughtered per day. It discharges into a medium-size stream about 7 m.g.d. of waste, of which approximately 5 m.g.d. is relatively clean cooling water. The balance is ordinary packing plant waste. The waste has been discharged into the river with only minor treatment for a number of years and it is now evident to the management that such practice will soon have to be discontinued. Consequently, steps were taken to have some preliminary studies made.

The first step in these studies was to provide facilities for the continuous measurement of flow and for the collection of daily samples of the combined wastes as they left the plant by automatic sampling machines. The resulting composite samples were sent to the laboratory for the customary analyses.

Method of Determining B.O.D.

As a labor-saving device, the 5-day B.O.D. values were obtained indirectly by determining the oxygen consumed using the iodate oxidation method developed by Johnson (1).

Both the iodate determination and the regular biological determination were first run on a large number of samples to determine the correlation between the two. It was found that 60 per cent of the oxygen consumed corresponded very well with the 5-day B.O.D. as determined by the biological method. In most of the data where 5-day B.O.D. values are mentioned, they have been determined by the iodate oxidation method using a factor of 60 per cent.

B.O.D. Results

It was found that the strength of the waste varied considerably, independent of the amount of raw material processed in the plant. To elucidate this, records were kept of the total pounds of live animal weight processed

* Presented at 25th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; New York, N. Y.; Oct. 6–9, 1952.

in the plant during the day and the volume and strength of the waste. From such values could be calculated the pounds of B.O.D. present in the sewage per 1,000 lb. of live weight. On days when the kill is relatively light, there appears to be very little correlation between these two. However, on days of heavy kill the pounds of B.O.D. in the sewage increased with an increase in the pounds of live weight handled.

Data were collected for one year, and out of these were selected all those days in which the kill exceeded 1,500,000 lb. of live weight. Figure 1 shows the frequency distribution of the pounds B.O.D. per 1,000 lb. live weight. Values given are not absolute, but relative, frequencies. Thus, a strength of 23 lb. B.O.D. per 1,000 lb. live weight occurred at a frequency of 7 as compared to a frequency of 3 for a strength of 21 lb.; in other words, a strength of 23 lb. per 1,000 lb. live weight was encountered a little more than twice as often as a strength of 21 lb.

It is to be noted that when the data are arranged in this fashion, the frequency distribution follows a bi-modal curve, showing a slight skewness to the right and with two peaks, one at 23 and one at 32 lb. Such a bi-modal distribution suggests at once that there exists a variation in plant practices. It is obvious that if the plant practice that leads to the higher values can be eliminated, there will be a substantial reduction in the average strength of the waste, and since treatment plants should be designed to handle the peak loads, it will be possible to cut the cost of treatment facilities considerably if these plant practices can be altered. The difference between the two peaks represents approximately 10 lb. of B.O.D. per 1,000 lb. of live weight, or, for an average kill of 2,000,000 lb. of live weight per day, this represents a total load of 20,000 lb. B.O.D.

Strong Wastes

In addition to the studies made on the composite waste, other studies were made on composite samples collected from various points or stations within the packing plant. The results obtained from these observations showed clearly that some operations result in strong wastes and some in relatively weak ones. In fact, some of the wastes were strong enough to lead to the suspicion that they could profitably be sent to evaporators. The question then arises as to how strong wastes must be before they can be profitably evaporated. There are, of course, a number

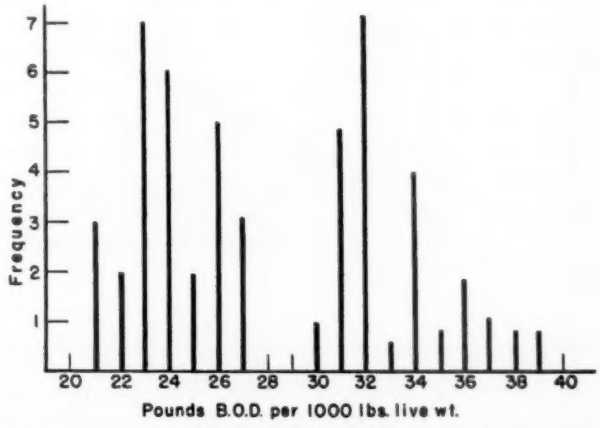

FIGURE 1.—Frequency distribution of pounds B.O.D. per 1,000 lb. live weight.

of factors involved in this problem. Important ones are:

1. The cost of steam.
2. Labor cost in collecting the waste and the operation of evaporators.
3. The overhead charges on investment for evaporators.
4. The value of the dry materials recovered following evaporation.

These factors may vary from plant to plant so that one cannot take the figures applicable at one plant and assume that they will necessarily hold for another. However, the general principle should at least be transferable. If the strength of the waste to be evaporated is known, it should be possible to calculate a net cost of evaporation per pound of dry material recovered. The sale value of the dry product can then be used to offset the cost of evaporation either entirely or in part.

By making some rather broad generalizations, it is also possible to calculate the cost of waste treatment per million gallons of waste. For a given industry this cost will generally vary with the strength of the waste. A stronger waste will require more adequate treatment and, therefore, in general, will cost more per gallon for treatment. Here again, the figures cannot be transferred from one industry to another, because local conditions may affect these costs, but the general principles will hold.

Cost Comparisons

In this particular case, the estimates used resulted in a cost of $100 per m.g. if the strength was 2,000 p.p.m. This increased at the rate of about $20 for each increase of 1,000 p.p.m. in the strength of the waste.

From the estimates it was possible to construct a cost nomogram (Figure 2), in which the net cost of evaporation varied with the strength of the waste for a given value of the dry solids recovered. For example, if the dry solids are worth 4¢ per pound and the waste has a strength of 11,000 p.p.m. of B.O.D., the net cost of evaporation is zero. In this case the value of the raw materials recovered is just sufficient to cover all of the cost of evaporation. If the strength is reduced to 10,000 p.p.m. and the solids are worth 4¢ a pound, the net cost would be approximately $400 per m.g.

It is to be noted that for a strength of waste somewhere between 10,000 and

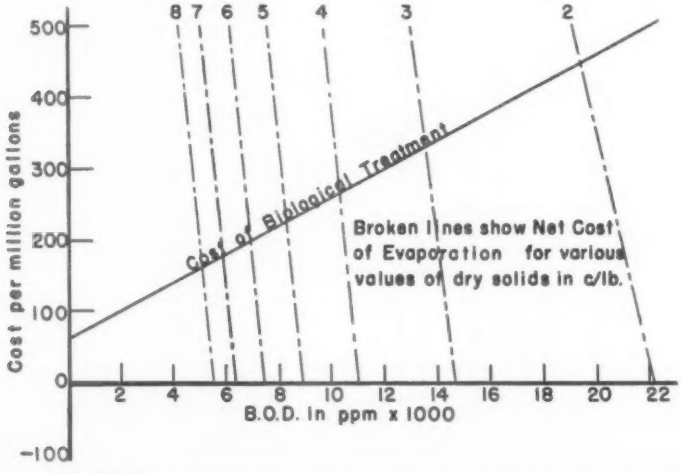

FIGURE 2.—Cost nomogram for net cost per m.g. of evaporation.

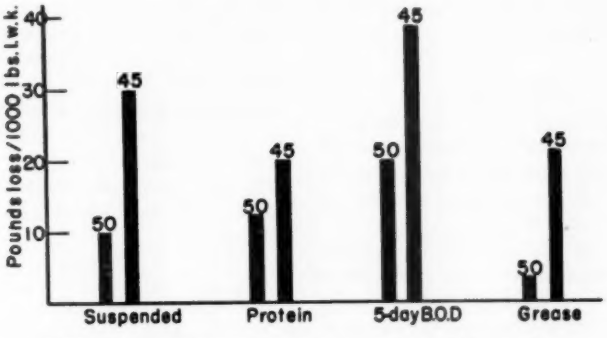

FIGURE 3.—Comparative loss in wastes, 1945 *vs.* 1950.

11,000 p.p.m., the net cost of evaporation will be equal to the cost of waste treatment. Consequently, any waste stronger than this can be evaporated at less cost than the cost of sewage treatment.

From such a cost analysis, one can arrive at a reasonable decision as to what waste should be evaporated. In the particular plant in which these studies were made, it was decided that any waste having a B.O.D. in excess of 14,000 p.p.m. should be sent to the evaporators; wastes weaker than that should be treated as sewage. With these values in mind, a survey was then made within the plant to find out what wastes should be diverted to the evaporators. It was soon discovered that the evaporating capacity was inadequate. This was corrected by the installation of new evaporators.

Re-Study of Plant Processes

During the studies it was learned that the strongest waste encountered in any of the plant operations was the tank water and that the dumping of this tank water had been responsible for the bi-modal distribution indicated earlier.

It also was observed that there were a few stations in the plant which produced wastes just slightly on the weak side of what was considered proper strength for evaporation. The processes used in such stations were studied carefully and it was found that in a number of cases slight modification in the methods of operation would yield a stronger waste and less volume, so that the waste could then be diverted to the evaporators.

A survey of all plant operations and a diversion of the strong waste to the evaporators takes considerable time. Over a period of months and years, if this program is followed diligently, it can make profound changes in the strength and character of wastes needing treatment.

A factor that contributes a great deal to the strength of packing plant wastes is grease or fats. Much of this material can be recovered in settling tanks having short detention periods. This was done, with the result that a large amount of grease was recovered, which also brought about a substantial reduction in the B.O.D.

Waste Reductions

After five years of such in-plant studies, marked changes have occurred in the strength and character of the wastes. They can best be summarized by Figure 3, which shows the comparative amount of materials lost in the sewage per 1,000 lb. of live weight for the year 1945 as compared with the year 1950. It should be noted that the suspended matter has been reduced from 30 to 10; the protein from 20 to 12; the 5-day B.O.D. from 37 to 20;

and the grease from approximately 25 to approximately 5.

Conclusion

These studies and the in-plant changes represent a considerable expenditure of time and capital investment. But if one considers the changes that have been effected in the strength and nature of the waste and the consequent decrease in the ultimate cost of the waste treatment plant, it can be stated that the studies and the expenditures have been worth while. Accompanying these changes has been a substantial recovery of grease and proteins which have market value. It is not known just how this has affected the economies of the plant operation, but it is safe to state that income received from the sale of these recovered products has been considerably more than the cost of the changes that were necessitated.

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DISCUSSION

By M. D. Sanders

Chemical and Sanitary Engineer, Swift and Company, Chicago, Ill.

This account of studies of industrial waste strengths at a large meat-packing plant merits the close attention of all meat-packing plant operators. The data presented indicate that the plant provided the equivalent of 50 per cent purification of its waste by collecting and processing liquids that were formerly discharged to the sewers.

A logical approach is suggested to the problem of disposition of strong liquid wastes where the value of the product is less than the cost of recovery. Sound business judgment will support the reasoning, if the cost of recovery can be compared with the cost of destruction. Any meat-packing plant having a breakdown of the cost of waste treatment into its component parts can determine, by the method outlined, whether it is cheaper to sewer or to recover strong liquid wastes.

One gets the impression from this paper that the rendering department of the meat-packing plant studied, provided a fertile field for reduction of waste strength. Therefore, some comments on what may be done to reduce the strength of waste leaving this department seem appropriate, particularly for the benefit of those not familiar with processing methods and equipment in the meat industry.

Figures 1 and 2 are flow sheets depicting the two types of equipment used in rendering animal tissue. A considerable part of the slaughtered animal is processed by one or the other of these methods into two end products—pure fat, and the residual dry mixture of protein and bone known either as tankage or cracklings. Dry rendering produces no liquid products that may reach the sewerage system, except for water used for condensing the vapor leaving the melters. On the other hand, wet rendering produces tank water as an intermediate product, and this was apparently one of the major sources of high B.O.D. in the studies of Professor Halvorson. Tank water is made up of the moisture originally in the raw tissue, condensed steam used in the process, and hydrolysis products from the animal tissues. Undiluted tank water may contain 6 to 8 per cent solids, of which about 80 per cent are protein. Multiple-

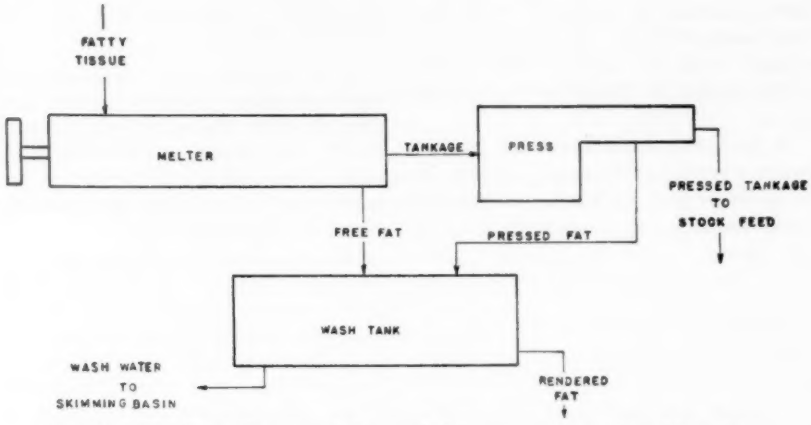

FIGURE 1.—Flow diagram of dry rendering process in meat-packing plant.

effect vacuum evaporators are usually employed to concentrate this material, preparatory to combining it with pressed tankage for final drying.

The American Meat Institute, in its "By-Products of the Meat-Packing Industry," suggests the following precautions to be taken so that maximum recovery of tank water is effected:

1. There should be no sewer connections in the pressroom, since press drainage must be collected and pumped to tank-water storage.

2. Steam coils, used to keep tank water hot in processing or storage, should be kept in repair to avoid diluting the tank water with steam condensate or, conversely, admitting tank water to the steam condensate lines where it may find its way to the sewer.

3. The previous week's, month's, and year's yield of stick (concentrated tank

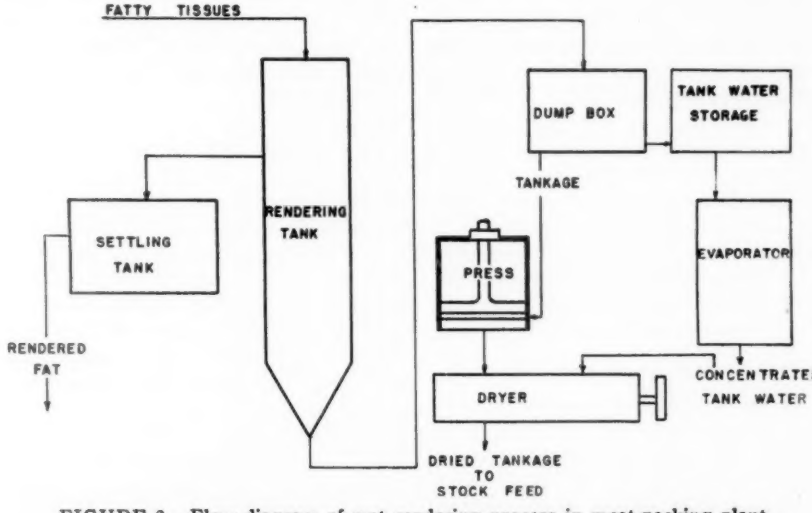

FIGURE 2.—Flow diagram of wet rendering process in meat-packing plant.

water) should be compared with current production on a per 1,000 lb. live weight basis, to detect changes that might point to losses not otherwise noted.

4. Maintain tank water in storage tanks, awaiting evaporation, at 180° F. or more to prevent spoilage. Spoiled tank water often foams in vacuum evaporators, contaminating the condensing water.

It is believed that experience will show that sound practices such as these, coupled with adequate evaporator capacity, will result in practically complete utilization of all tank water, and, therefore, in its elimination as a major factor in waste disposal.

INDUSTRIAL WASTES REFERENCE BULLETINS

Useful and informative publications on two difficult industrial wastes have recently been made available.

The first, entitled "Slaughterhouse and Packinghouse Wastes," is a comprehensive bibliography and compendium of abstracts of articles relating to those wastes. Prepared by Donald D. Gold, the 45-page booklet may be obtained as Bulletin Number 14 (May, 1951) from the Engineering Experiment Station, University of Tennessee, Knoxville, Tenn.

The second, published by the Ohio River Valley Water Sanitation Committee, is entitled "Methods for Treating Metal-Finishing Wastes." The 72-page booklet, compiled as a reference data publication by the Commissions' Metal-Finishing Industry Action Committee, evaluates the various disposal methods and their applicability to specific waste control conditions in the metal-finishing industry. Phases covered by the manual include process waste sources, cyanide treatment methods, acid treatment, oil and paint treatment, metal recovery, and final disposal methods. An excellent 4-page bibliography of 61 references is included. Copies are available at $2.00 each from the Ohio River Valley Water Sanitation Commission, 414 Walnut St., Cincinnati 2, Ohio.

TREATMENT AND DISPOSAL OF MILK WASTES *

By S. I. Zack

Chief Sanitary Engineer, Gannett Fleming Corddry and Carpenter, Inc., Harrisburg, Pa.

In the past five years or so the author has had the interesting task of appraising the operations and waste waters from about 20 milk products plants, for the purpose of either prescribing or executing means for pollution control; or in behalf of the municipality or the industry to develop the basis for, and to establish the actual sewer rental to be charged for disposal of the waste waters. The smallest plant handled about 10,000 lb., the largest 600,000 lb. of milk per day.

Operations and Source of Waste Waters

The operations involved may be classified as receiving of milk in cans from local sources or in tank trucks from more remote sources; pasteurizing; cooling; bottling; cream separation; the making of butter, cheese, ice cream, and ice cream mixes; milk evaporation; condensation; sterilization; and the production of dry milk powders. All plants operated on a 7-day week. Many of the individual operations for the same type of plants were identical, but no two plants were exactly alike in their milk receipts, products produced, volume and strength of waste waters discharged, or hours per day in operation.

Waste waters discharged contained milk or milk products from the washing of bottles, cans, tank trucks, plant equipment, and floors, and from the operations of evaporators and dryers. Except for leaks, water used strictly for cooling or sterilizing cans of evaporated or condensed milk carried very little or no milk contamination.

Method of Evaluating Wastes

By determining the seasonal pattern of milk receipts or milk produced in each individual case, and gaging and sampling the wastes over a 2- to 5-day period at any time, but preferably during the flush or peak season, a practical evaluation of the pollution load representing waste volume and strength was made to be suitable for design of milk waste treatment facilities and for establishing annual costs for treatment or for setting up sewer rental charges. Flow measurements were made and samples proportional to flow were taken, usually every 15 or 20 min. during the operating period of the day. Analyses were made of samples composited during the operating period.

In the section of the country involved, lowest stream flows occur when milk operations are at high level. Therefore, treatment plant capacity must provide for peak, or near peak pollution loads, which occur during two or three summer months. The Pennsylvania Sanitary Water Board requires that design be based on the three peak consecutive days of the year. Annual treatment costs and rental charges are, therefore, greatly influenced by these peak operations.

Seasonal Pattern of Milk Handled

The seasonal pattern or trend in quantities of milk received and processed is similar, whether the plant is large or small, and whether the plant is a receiving station only, or milk is received and milk products processed.

* Presented at 25th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; New York, N. Y.; Oct. 6–9, 1952.

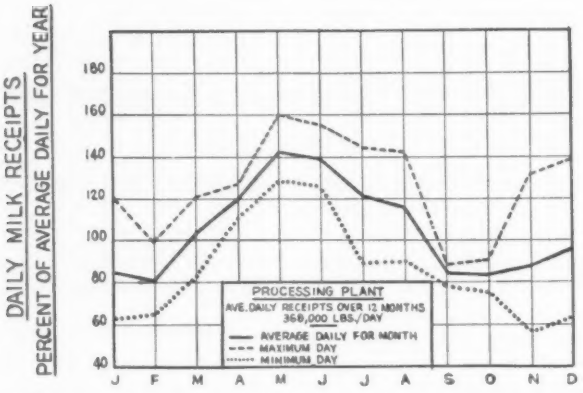

FIGURE 1.—Milk processing plant; variations in average, maximum, and minimum daily milk receipts.

Maximum receipts and production usually occur during May, June, and July, tapering off to a minimum during the fall and early winter months.

The greatest variation between maximum and minimum receipts and/or production occurs at receiving stations and processing plants that rely on raw milk solely from local sources. The least variations occur in bottling plants supplying milk daily to customers. Some bottling plants also make ice cream, in which case milk handled increases somewhat during the summer. In a milk receiving station handling an annual daily average of 20,000 lb. per day, daily milk receipts may vary from a minimum of 12 per cent to a maximum amounting to 160 per cent of the annual daily average. In a processing plant the range may be somewhat less, with the minimum day about 60 per cent and a maximum day of 160 per cent of the annual average. In making cheese at one of the plants, the milk used daily for setting and blending

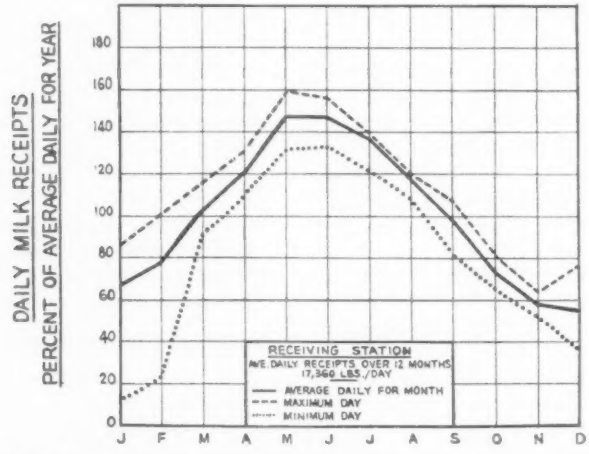

FIGURE 2.—Milk receiving station; variations in average, maximum, and minimum daily milk receipts.

varied from a small percentage to 220 per cent of the daily average for the year.

Typical variations in milk received at receiving stations and processing plants during a yearly period are shown in Figures 1 to 4.

Variations in Rates of Milk Wastes Discharged

Milk from local sources is usually brought into a receiving station in cans and occasionally in tank trucks. Receiving of milk starts between 6:00 AM and 7:00 AM; by 2 PM the cans, plant equipment, and floors are washed up and ready for the next day's receiving. Most processing plants, especially the larger ones, usually operate on a two-shift basis and sometimes operations run into a third shift. In both types of plants there are variations in wastes discharged, with the greatest variation occurring at receiving stations.

Typical variations in the rates of wastes discharged during the operating period at a receiving station where milk was pasteurized, cooled, and stored, and at a processing plant where milk was received, separated, evaporated, and dried to a powder, are shown in Figure 5. Peaks up to eight times the 24-hr. average flow occurred at this receiving station during the washing of cans and equipment. The entire operating period, however, was less than 8 hr. per day. The peaks at a processing plant were only about twice the average 24-hr. rate. In this case the actual operating period was about 20 hr.

Variations in rates of discharge at a bottling plant, which received and bottled milk and made ice cream and a small amount of cottage cheese, and at a large cheese plant, are shown in Figure 6. Peak rates of milk waste discharged at a cheese-making plant and at a bottling plant, each of which was operating about 12 hr. per day,

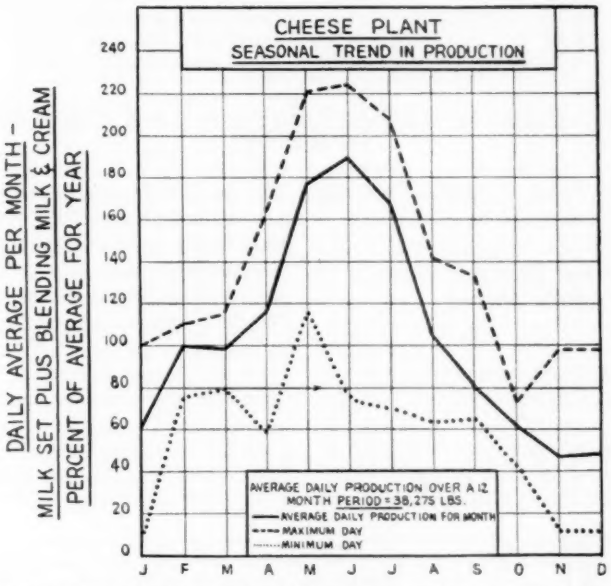

FIGURE 3.—Cheese plant; variations in average, maximum, and minimum daily milk receipts.

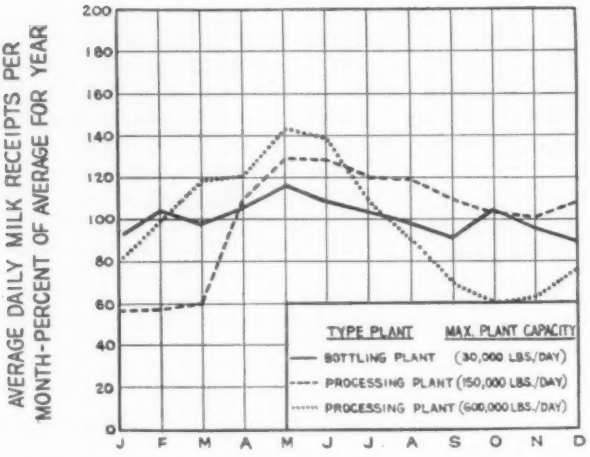

FIGURE 4.—Seasonal trends in average daily milk receipts at plants of various types and capacities.

were about 350 per cent of the average 24-hr. rate.

Volume and Pollution Load of Milk Wastes

The volume and pollution load of wastes discharged from milk plants of various types depends entirely on the conservation in practice; that is, the effort made to conserve water and to prevent the loss of milk and milk products into the waste waters discharged. The loss of 1 lb. of whole milk results in a 5-day B.O.D. of 0.1 lb. Therefore, a loss of only 1 per cent of the milk handled amounts to 1 lb. of B.O.D. in the waste waters for every 1,000 lb. of milk handled. Unless the milk losses are sufficiently high to affect economy in plant operations, nothing is done about them until the particular milk company is confronted with the costs for treatment of its wastes, whether by its own plant or in a municipal sewage plant. From the standpoint of economy in

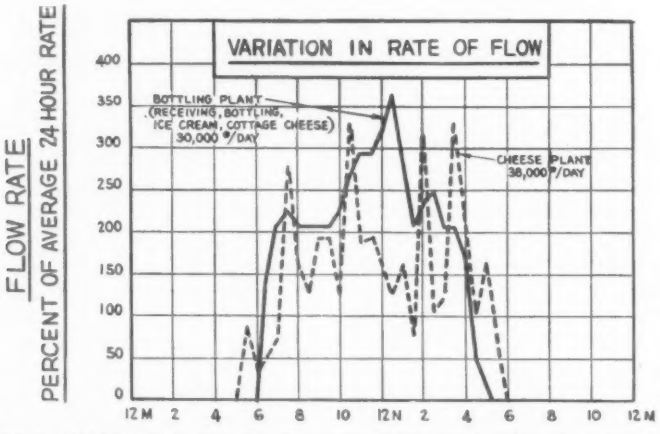

FIGURE 5.—Variations in rate of milk waste discharge, bottling and cheese plants.

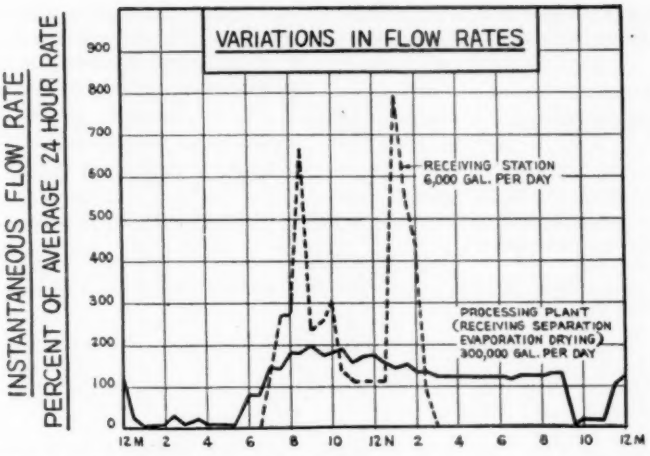

FIGURE 6.—Variations in rate of milk waste discharge, processing plant and receiving station.

milk operation, even a 2 per cent loss does not appear to disturb the management of a milk plant. In several bottling plants and a cheese plant even much higher losses were tolerated until waste disposal costs became a factor.

The Pennsylvania Sanitary Water Board has adopted standards developed in cooperation with the Pennsylvania Association of Milk Dealers, Inc. These standards indicate the B.O.D. in the wastes for each operation in a milk plant where an average degree of "conservation" or so-called "good housekeeping" is practiced.

The volumes of waste and B.O.D. per 1,000 lb. of milk received for a number of plants investigated, and the B.O.D. as set forth by the Pennsylvania Sanitary Water Board, are shown in Tables I and II.

No correlation was found from one plant to another in the quantities of waste waters discharged or the pounds of B.O.D. contained in such waste waters. Cooling waters and condensate

TABLE I.—Volumes of Milk Wastes from Various Capacity and Types of Milk Plants

Processes in Operation	Plant	Maximum Capacity (lb. milk/day)	Wastes (gal./1,000 lb.)[1]	
			Cooling Water and Cond.	All Other
Receiving, bottling, ice cream and cream cheese manufacturing	A	30,000	400–600	700–1,200
Receiving station	B	65,000	——	100–200
Receiving, pasteurizing, separation, condensing, and spray drying	C	150,000	2,000–3,000	175–225
Receiving, condensing, canning, and sterilization	D	400,000	1,000–1,500[2]	40–80
Receiving, pasteurization, separation, condensing, and spray drying	E	600,000	1,000–2,000	300–400
Receiving, pasteurization, separation, condensing, spray and roll drying, and ice cream mix making	F	600,000	1,200–1,800	150–200
Cheese plant	G	90,000	——	115–340

[1] Gallons per 1,000 lb. of milk received, as determined by gagings.
[2] Includes sterilization water.

TABLE II.—B.O.D. of Milk Wastes from Various Capacity and Types of Milk Plants

Processes in Operation	Plant	Maximum Capacity (lb. milk/day)	B.O.D. (lb./1,000 lb. milk)[1]			
			Analyses[2]			Water Standards[3]
			Cooling Water	All Other	Total	Total
Receiving, bottling, ice cream and cream cheese manufacturing	A	30,000	0.05–0.15	4.00–6.50	4.05–6.65	1.8
Receiving station	B	65,000	——	0.40–0.60	0.40–0.60	0.9
Receiving, pasteurizing, separation, condensing, and spray drying	C	150,000	0.10–0.20	2.25–2.75	2.35–2.95	2.3
Receiving, condensing, canning, and sterilization	D	400,000	0.20–0.50[4]	0.25–0.50	0.45–1.00	1.2
Receiving, pasteurization, separation, condensing, and spray drying	E	600,000	0.20–0.50	0.75–1.00	0.95–1.50	2.2
Receiving, pasteurization, separation, condensing, spray and roll drying, and ice cream mix making	F	600,000	0.10–0.20	0.60–0.80	0.70–1.00	2.8
Cheese plant	G	90,000	——	4.65–7.70[5]	4.65–7.70[5]	4.7

[1] Pounds per 1,000 lb. milk received.
[2] Analyses of daily composite samples.
[3] Pennsylvania Sanitary Water Board Standards.
[4] Includes sterilization water.
[5] Whey not included.

discharged range from 400 to 3,000 gal. per 1,000 lb. of milk, and the quantity depended on temperature of the available water and the seasonal temperatures. All other waste waters discharged depended on the operations involved and the effort made to conserve water.

The pounds of B.O.D. in the waste waters discharged per 1,000 lb. of milk received and/or processed also varied over a wide range from one plant to another. B.O.D. in milk wastes ranged from 0.4 to 7.70 lb. per 1,000 lb. of milk received or handled, the highest B.O.D. being in the wastes from a bottling plant and a cheese plant. The B.O.D. in the wastes from the various plants, except the bottling plant, compared favorably or were lower than indicated by the standards of the Pennsylvania Sanitary Water Board. The B.O.D. in the wastes from the bottling plant was more than three times the B.O.D. according to the standards.

Conservation to Reduce Waste Volume and Strength

At the receiving station designated in Tables I and II as Plant B, through a concerted effort to save water, the daily discharge of waste waters was reduced from an average of 190 gal. before the effort to conserve, to 57 gal. per 1,000 lb. of milk received, after the effort to conserve. No similar reduction, however, took place in the B.O.D. content of the wastes. The B.O.D. actually increased from 0.32 to 0.48 lb. per 1,000 lb. of milk received.

In Plant G—making cheese—milk, cream, and cheese spoilage; whey; cheese from broken bags; and possibly other milk or milk products, all went down the drain. The B.O.D. content of the wastes on some days reached as high as 50 lb. per 1,000 lb. of milk handled, of which 20 lb. was due to the whey discharged. Confronted with an apparently costly problem of waste treatment and disposal, the whey was taken

out and a conservation program to reduce losses was put into effect. This resulted in a 20 per cent reduction in volume of waste waters and in a B.O.D. of 4.65 to 7.70 lb. per 1,000 lb. of milk received after the reduction. The Sanitary Water Board standards indicated that a B.O.D. content of 4.7 lb. per 1,000 lb. of milk received might be anticipated for the wastes from a plant of this type.

In a bottling and ice cream plant where little or no effort had been made to prevent losses, the establishment handling about 30,000 lb. of milk per day was faced with a monthly sewer rental charge of about $900 per month under a newly established sewer rental ordinance. It took very little effort on the part of the management to reduce the volume and strength of the wastes discharged to the extent of reducing the rental charge to about $300 per month.

The pollution load of milk wastes can be greatly reduced by the practice of "conservation" or so-called "good housekeeping." This requires the installation of equipment and/or devices such as drip savers, boilover and entrainment controls, substitution of rubber for fiber gaskets in vacuum lines, the use of compression-type faucets on hoses used for washing down floors and equipment, etc. Whey and spoiled milk should be trucked away and not dumped through the floor drains. Each and every employee, as well as plant management, must be made to understand the importance of waste saving, however, if a good housekeeping program is to show any long-range benefits.

Condensate and Cooling Waters

Cooling waters not coming in contact with milk carry no pollution, of course, unless leaks or spillages occur. Condensate waters from evaporating equipment, except for boilovers, have a very low B.O.D. content and such waters are suitable for discharge to a stream without treatment. The B.O.D. strength of such clear condensate is usually lower than in effluents resulting from treatment of the concentrated milk wastes. It is considered to be more economical to install automatic liquid level controls, entrainment separators, and other devices in milk evaporating equipment, to prevent boilovers and losses by entrainment, than to provide treatment for such wastes.

The B.O.D. strengths of condensate waste waters, when very little or no boilover or milk entrainment occurred during operation of evaporators, are compared with such waters when boilovers and other losses are known to have occurred, as follows:

Plant	B.O.D. in Condensate Waste Waters			
	Parts per Million		Lb. per 1,000 Lb. Milk Handled	
	Low Milk Losses	High Milk Losses	Low Milk Losses	High Milk Losses
D	27.0	46.0	0.20	0.51
E	2.5	82.0	0.02	1.48
F	6.0	—	0.15	—

Treatment and Disposal of Milk Wastes

As yet there is no standardized method for the treatment or disposal of milk wastes to prevent stream pollution. Each case must be appraised on its merits and a proper solution worked out.

Since the suspended solids content is not an important factor in the pollution load of milk wastes, very little reduction in pollution load can be effected by primary treatment consisting of plain sedimentation of these wastes. Any treatment to be effective, therefore, must be capable of reducing the B.O.D. of the soluble organic solids. This requires some form of partial or complete treatment of the biological type. Some forms of chemical precipitation are suitable, but not economical, for reducing the organic pollution load of milk wastes.

Where the stream flow is not too

critically low and the pollution load not too high, effective improvement in stream conditions can be accomplished by spreading the 8-hr. discharge uniformly over 24 hr. of the day. Unless the stream flow is appreciable, this method of final disposal is probably limited to milk plants handling up to 20,000 lb. of milk per day. By utilizing an aerated holding or equalizing tank, the wastes being held can be kept in a fresh condition and some measure of B.O.D. reduction can be obtained.

In recent years, for complete treatment of milk wastes, the various forms of single- or double-stage high-rate recirculating rock filters have been most popular, although a number of activated sludge-type aeration plants have also been used. The filter plants have been simpler to operate and maintain, whereas the activated sludge plants have required more skilled operation and more maintenance. Furthermore, clogging of the porous diffusers, due to slime, has been a problem.

Most plants provided digestion tanks for decomposition of sludges formed in biological treatment of milk wastes and sand beds for drying undigested or digested sludges. Very little information is available, however, on the amount of sludge left after digestion.

More recently, several types of jet aerators have become available which are claimed to be non-clogging. Furthermore, results of research indicate the possibility not only of providing complete treatment for the liquid wastes, but also of digesting or stabilizing the solids by long-period (24-hr.) activated sludge aeration with excessive amounts of air. This type of treatment seems to be more economical for small daily quantities of wastes of higher strengths than for large daily quantities of wastes of weaker strength.

When provided for by design, milk wastes can be treated with sewage at municipal sewage treatment plants. Holding or equalization tanks should be provided to smooth out, preferably over a 24-hr. period, the milk wastes delivered for treatment to a municipal sewage plant or to a separate milk waste treatment plant, unless the volume and strength and variation in flow of milk wastes are not appreciable. The wastes in such holding or equalizing tanks should be kept fresh by aeration or liming.

Results of Sewage and Milk Waste Treatment

The milk waste load at Mechanicsburg, Pa., amounts to 5 per cent by volume and 15 per cent on a B.O.D. basis. The sewage, including milk waste, is treated with a two-stage, high-rate, recirculating-type filter plant. Sludge is digested in a heated covered tank. The total B.O.D. load, averaging about 685 lb. per day, is applied to the filters at a rate of 0.72 lb. per day per cubic yard of rock. This is about 42 per cent of design capacity. Effluent from the first filter in the ratio of about 1 effluent to 1 incoming sewage is now returned to the primary tank and in the ratio of about 1 effluent to 1 incoming sewage is recirculated from the secondary tank to the second filter. The filters are in excellent condition with no pooling or clogging. The incoming sewage has a B.O.D. of from 225 to 300 p.p.m. The over-all treatment results in 92 to 95 per cent removal, with an effluent containing an average of about 18 p.p.m.

Difficulties encountered in the operation of a standard trickling filter receiving sewage from the village of Arcade, N. Y., and a portion of the milk wastes from the Borden Company plant were overcome by the recirculation of the effluent from the secondary settling tank back to the filter in a ratio of 1.0 to 2.0 effluent to 1 of incoming sewage and waste.

The village sewage plant is designed for a flow of 250,000 g.p.d. from a domestic population of 2,500 persons. The present connected load is estimated to be about 1,800 persons. Based on tests made before recirculation was started, the total flow received at the

treatment plant was found to be 196,000 g.p.d., of which 16,000 g.p.d. came from the milk plant. The B.O.D. of the milk wastes amounted to 85 lb. per day, equivalent to a population of about 500 persons. Even though the loading on the filter was only 285 lb. per acre foot per day, well within allowable design limits, the rock filter was ponding badly, displayed none of the typical green growths, and the rock media was clogged with black slime. The filter effluent was hardly better than the Imhoff tank effluent.

Coincident with the starting of recirculation, during the middle of July, 1951, the filter influent was heavily chlorinated and the filter backflooded several times. Considerable slime was thus released. Within a month after recirculation was started, the ponding stopped and a satisfactory effluent was obtained. Results are still reported as being satisfactory after more than a year of recirculation, even though the final settling tank does not have adequate capacity for proper settling of the filter effluent.

Based on a test made during the middle of August, 1951, the total flow to the treatment plant amounted to 187,000 g.p.d., including 53,000 g.p.d. of milk wastes with a B.O.D. content of about 100 lb. per day.

Even though the B.O.D. loading on the filter per acre foot was no less than during the May tests, the plant effluent contained only 15 p.p.m. of B.O.D., representing an over-all removal of 92.5 per cent through the entire plant.

Milk Waste Disposal to Drainage Ditch

The Arkport Dairy, handling a maximum of about 600,000 lb. of milk per day, encountered pollution difficulties by discharging to a nearby creek about 900,000 g.p.d. of waste with a total B.O.D. load of 420 lb. About 300,000 gal. of the more concentrated wastes with a B.O.D. content of about 150 p.p.m. (360 lb. per day), were taken out of the creek and discharged to an advantageously located, normally dry drainage ditch on its own property. This ditch lies along a strip of land 66 ft. wide parallel to the creek about 1.5 mi. from the Canisteo River. Although the ditch has some obstructions, creating pools, it has an over-all fall of about 1.7 ft. per 1,000 ft. This strip of land, formerly a railroad right-of-way, was purchased by the company at a very nominal price. Odors due to discharge of the milk wastes developed along pools which existed in certain stretches of the ditch.

In an endeavor to create pools for controlled retention, to provide aeration for oxidation of organic matter, and for odor suppression, a series of six small dams were constructed in the first 3,000 ft. of the ditch. Sodium nitrate was applied manually twice a day over the surface of those stretches where septic conditions were evident. Initial dosages of 400 lb. per day were reduced to about 200 lb. per day, amounting to about 0.6 lb. of sodium nitrate per pound of B.O.D. in the milk wastes discharged to the ditch.

Although, due to poor construction of the dams, the fullest possible aeration was not developed, the addition of sodium nitrate resulted in effective suppression of odors. A gradual depression of dissolved oxygen took place in the ditch for the first one-half mile. In the stretches beyond, algae growths were evident and a gradual increase in dissolved oxygen resulted up to the point of saturation. The waters at these lower extremities, about 1 mi. below the point where the milk wastes entered the ditch, were clear, odorless, and had a B.O.D. content of less than 10 p.p.m.

It is apparent that by improving the dams, possibly adding a few more, and excavating the obstructions in the lower extremities of the ditch to permit free flow of wastes through the ditch, the waste waters delivered to the Canisteo River will be free of objectionable organic pollution load and the

sodium nitrate required to suppress odors can be greatly reduced.

The discharge to the creek of the other 600,000 g.p.d. of dilute wastes (12 p.p.m. B.O.D.) has thus far raised no complaints.

Disposal of Milk Wastes to Municipal Sewers

It is usually found to be more advantageous from an economical and practical standpoint to discharge milk wastes to municipal sewers and treatment plants when it is possible to do so, than to provide a separate plant for treatment of the wastes. This is particularly so because many receiving, bottling, and processing plants are located right in the municipality.

In Pennsylvania, many sewer systems and sewage treatment plants have been recently constructed through the sale of authority bonds, with sewer rentals charged to residential, commercial, and industrial users of the works to cover annual fixed and operating costs and the setting up of required reserve funds.

Such rentals are based either on fixtures or water use, or sometimes on measured waste in the case of industries. Rentals for industrial wastes are adjusted in accordance with the content of suspended solids, and B.O.D., in the case of complete treatment plants, or chlorine demand in the case of primary treatment plants.

In the case of milk wastes, suspended solids content is usually less than the suspended solids content of sewage and in any case does not materially affect rentals. The B.O.D. content and chlorine demand are usually higher than those of sewage, and rentals for milk waste run higher than the base charge, based on fixture or water charge.

TABLE III.—Sewer Rental Charges for Milk Wastes at Various Type and Capacity Sewage Treatment Plants

Municipality[1]	Type of Project	Present Population	Sewer Rentals ($/1,000 gal. milk waste)[2]		
			Base Charge	B.O.D. Charge	
				300 p.p.m.	600 p.p.m.
Lemoyne	Primary treatment plant and sewers	4,600	0.35	0.39	0.54
Danville	Primary treatment plant and interceptors	7,050	0.25–0.20[3,4]	0.27–0.22	0.32–0.26
Catawissa	Primary treatment plant and interceptors	1,970	0.50[4]	0.54	0.64
Middleburg	Primary plant, sewers, and interceptors	1,270	0.67	0.74	1.04
Bloomsburg	Intermediate treatment plant and interceptors	10,600	0.35–0.15[5]	0.37–0.16	0.42–0.19
Mechanicsburg	Complete treatment plant and sewers	6,770	0.28	0.34	0.55
Shippensburg	Complete treatment plant and sewers	5,710	0.25[6]	0.26	0.31
Gettysburg	Complete treatment plant additions	7,040	0.40–0.10[7]	0.44–0.11	0.62–0.16

[1] All in Pennsylvania.

[2] Suspended solids and chlorine demand taken into consideration where applicable.

[3] $0.25 up to 100,000 gal.; and $0.20 for everything over 100,000 gal. per quarter.

[4] Base charge 15 p.p.m. chlorine demand or less.

[5] $0.35 up to 200,000 gal.; $0.25 for next 400,000 gal.; and $0.15 for everything over 600,000 gal. per quarter.

[6] Base charge 250 p.p.m. B.O.D. and less.

[7] $0.40 up to 7,500 gal.; $0.33 next 37,500 gal.; $0.20 next 330,000 gal.; $0.13 next 375,000 gal.; $0.12 next 2,250,000 gal.; $0.10 for all over 3,000,000 gal. per quarter.

TABLE IV.—Typical Sewer Rental Costs per Unit of Milk Handled

Plant	Location	Milk Handled (lb./day)[1]	Waste (g.p.d.)[1]	Sewer Rental Costs	
				(¢/1,000 lb. milk)	(¢/qt. milk)
1	Bloomsburg	4,000	7,000	55	0.11
2	Lemoyne	24,000	20,000	46	0.09
3	Mechanicsburg	75,000	17,000	10	0.02
4	Gettysburg	10,000	10,000	35	0.07

[1] Average.

Rentals for milk wastes are fixed to provide ready-to-serve capacity in sewage plants for volume and strength of wastes during seasonal peaks.

The amount of sewer rental charge for milk waste is, of course, dependent on the quantity and strength of wastes in relation to the size of the municipality and the magnitude and scope of the project being financed by the rentals.

Typical rentals for handling and treatment of milk wastes of various strengths by various municipalities which have recently financed sewerage and sewage works through the sale of municipal authority bonds are presented in Table III.

The amounts of sewer rental charges vary over a wide range (from about $0.10 to $1.00 per 1,000 gal. of waste), depending on waste volume and strength; the lower cost being applicable to a large-volume, low-strength waste in a relatively large municipality, and the higher cost being applicable to a low-volume, strong milk waste in a small municipality. Reduced to the cost per quart of milk handled, sewer rentals amount to about 0.02¢ to 0.11¢ per quart, as shown for some typical cases in Table IV. It is obvious that conservative use of water and the extent of prevention of losses by so-called "good housekeeping" procedure can greatly affect the sewer rental charges to be paid to a municipality for treatment of milk wastes.

If the rate of milk waste discharged is high in proportion to the average rate of sewage flow provided for by design of the sewage plant, it is desirable that an equalizing tank be provided at the milk plant to limit the discharge of wastes to the sewers.

Summary

Milk handled by a plant varies from day to day throughout the year. A wide variation exists in the rates of milk wastes discharged during the course of the day and in the volume and strength from day to day. The volume and strength of milk wastes discharged are to a great extent dependent on practice in effect to conserve water use and prevent loss of milk. Milk wastes alone or with sewage can be treated by most types of biological-type treatment plants with capacity to handle the organic pollution in the sewage and milk wastes. These factors, therefore, must be considered in design of milk waste treatment plants, or in designing sewage plants to receive milk wastes.

In many cases milk wastes are discharged to the municipal sewage works because of location or practical advantage. Where a choice exists it will also be found more economical to do so except under unusual circumstances.

Sodium nitrate was found to be effective in suppressing odors caused by the accumulation of milk waste in pools of a drainage ditch, on private property, developed for disposal of milk wastes.

The examples of sewer rental charges for collection and treatment of milk wastes indicate that such charges amount to a fraction of a cent per quart of milk handled.

DETERMINATION OF LACTOSE IN DAIRY WASTES

By E. Hindin

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In the examination of dairy wastes, a need exists for a rapid but simple method for the determination of lactose.

The existing methods do not enable an accurate quantitative estimation of milk sugar if found in trace quantities. Either a new method would have to be devised or an existing one modified.

A search of the literature revealed the possibility of using the Benedict modification (2) of the Folin-Wu method (1) for the determination of glucose in blood, if slight changes be made.

Essentially, this method consists of the oxidation of a reducing sugar by a weakly alkaline copper tartrate solution. The resulting cuprous copper reduces a phosphomolybdic acid solution with formation of a blue-colored solution. Since all reactions are quantitative the method is reasonably accurate.

The reproducibility of results has been questioned by many in the past. It is true that error due to operational technique may be great. With highly accurate pipets and complete knowledge of the method and its sources of error, it was found that with all precautions taken the error did not exceed 10 per cent, as shown in the experimental values dealing with the interference of lactic acid upon the method.

Method

1. Apparatus

1.1. Folin-Wu sugar tubes, 25-ml.
1.2. Pipets, 2-ml.
1.3. Pipets, 5-ml.
1.4. Mohr pipets, 10-ml.

2. Reagents

2.1. Standard lactose solution. Dissolve 1 g. of reagent grade lactose in 50 ml. of water contained in a 1-l. volumetric flask. Prepare a diluent by dissolving 2.5 g. of benzoic acid in 1 l. of boiling water. After cooling, dilute the lactose solution to volume.

2.2. N/12 sulfuric acid.

2.3. Sodium tungstate solution, 10 per cent. As prepared by Folin (1).

2.4a. Stock alkaline copper reagent. Dissolve 15 g. of anhydrous sodium carbonate, 3 g. of alanine, and 2 g. of sodium potassium tartrate in about 250 ml. of water. Add 3 g. of copper sulfate ($CuSO_4 \cdot 5H_2O$) previously dissolved in 100 ml. of water, to the mixture. The resulting mixture is transferred to a 500-ml. volumetric flask and diluted to volume. The alkaline copper solution will keep in good working condition from 6 to 8 weeks if it is refrigerated.

2.4b. Working copper bisulfite reagent. This reagent is prepared prior to its use by mixing 5 ml. of a 1 per cent sodium bisulfite solution to 100 ml. with the stock alkaline copper reagent.

2.5. Phosphomolybdic acid solution. To 150 g. of molybdic anhydride and 75 g. of anhydrous sodium carbonate contained in a large Erlenmeyer flask, add 500 ml. of water in small portions while shaking. The mixture is then heated to boiling, filtered, and the insoluble residue on the paper is washed with water until the total volume of the combined filtrate and washings amounts to 600 ml. To this solution add 300 ml. of phosphoric acid (85 per cent) and the resulting mixture is diluted to the volume of 1 l.

3. Procedure

3.1. Removal of protein. Transfer 8 ml. of N/12 H_2SO_4 to a 125-ml. Erlenmeyer flask. Add 5 ml. of the sample or an aliquot which has been diluted to 5 ml. Add 1 ml. of 10 per cent sodium tungstate solution and shake the flask. After allowing the coagulated protein to settle, filter through a No. 40 filter paper or denser paper if necessary.

3.2. Analysis of the protein-free sample. Place 2 ml. of the protein-free sample into a Folin-Wu sugar tube, add 2 ml. of the copper bisulfite solution, and mix the contents by vertical shaking. The mixing process should be repeated a few times.

After the tubes have been heated in a boiling water bath for 7 to 8 min., cool in cold water. When the tubes have cooled to room temperature, add 2 ml. of phosphomolybdic acid solution and mix as before. When the bubbling has ceased, dilute the mixture to the 25-ml. mark and mix by inverting the tubes a few times.

3.3. A blank must be run and treated exactly as the sample.

3.4. Compare the color of the sample with that of the blank, using a wavelength of 375 mμ. and 13-mm. cells for lactose concentrations from 100 to 5,000 p.p.m. If the probable range is from 0 to 200 p.p.m. of lactose, a 40-mm. cell should be used and a wavelength of 380 mμ.

3.5. Standard curves, from which the results are read, are prepared from data obtained by analyzing lactose solutions of appropriate strengths in the same manner as that used on the samples. A new standard curve should be determined prior to the use of a set of new reagents.

Stability of Color

The stability of the reduced phosphomolybdic acid colored solution was investigated, with results as follows:

Time (min.)	Scale Readings	Lactose (p.p.m.)
0	66	470
15	65	480
30	65	480
45	65	480
60	65	480

The experimental values indicate that the color remains stable throughout 1 hr.

Effects of lactic acid, if any, were also investigated. A solution containing 640 p.p.m. of pure lactose was used with various concentrations of lactic acid, as follows:

Lactic Acid (p.p.m.)	Scale Reading	Lactose (p.p.m.)	Error (%)
0	55.0	640	0.0
10	55.0	640	0.0
30	52.5	690	8.0
50	55.0	640	0.0
70	55.0	640	0.0
100	52.0	695	8.5
300	54.0	660	3.0
500	54.0	660	3.0
700	52.0	695	8.5

Lactic acid had little or no effect which created an error greater than the experimental error.

The Benedict modification of the Folin-Wu method as adapted for lactose in dairy waste was compared with the official methods as recommended by the A. O. A. C. (4) for lactose in milk, with the following results:

Description	Lactose (p.p.m.)			Error (%)
	Gravimetric[1]	Colorimetric[2]	Optical	
Homogenized milk	50,900	50,700	——	+ 0.2
Skimmed milk	60,600	60,500	——	+ 0.2
Buttermilk		34,500	20,500	−40.5
Skimmed whey		60,500	45,000	−25.6

[1] Modified Munson-Walker method.
[2] Modified Benedict method.

The colorimetric method compared favorably with the official gravimetric method. Both are based on the same principle, the reduction of the cupric copper in an alkaline copper tartrate solution. The two methods differ by

0.2 per cent. This is well within the experimental error.

There was a great difference between the optical method and the colorimetric method. The optical method is based upon the optical activity of lactose, whereas the colorimetric method is based upon the reducing properties of lactose. Since typical dairy wastes were used rather than a pure lactose solution, it was expected that the values for the lactose content would differ. Various factors (such as other reducing sugars, organic acids, animal gums, and unprecipitated proteins) may cause abnormal optical readings. The colorimetric method not only measures lactose, but also other reducing sugars and various aldehydes. Thus, it was not surprising that the variance was as great as it was.

Conclusion

In the analysis of dairy wastes, the method described herein proved satisfactory. The method can measure milk sugar from trace quantities up to and including the range where the sensitivity of the optical or gravimetric methods, as recommended by the Association of Official Agricultural Chemists, becomes great enough for an accurate analysis.

This method as adapted for lactose in dairy wastes was started prior to the publication of the "Determination of Total and Reducing Sugars in Citrus Wastes," by Wells, Rohrbaugh, and Doty (5). The latter procedure does not provide for protein removal, which is essential in analysis of lactose in dairy wastes.

Acknowledgment

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PURDUE INDUSTRIAL WASTE CONFERENCES

The Eighth Purdue Industrial Waste Conference is scheduled to be held in the Memorial Union Building, Purdue University, Lafayette, Ind., May 4–6, 1953. As in previous years, separate sessions are planned for major waste groupings, with both water and air pollution topics being included. Information regarding the Conference program and housing arrangements may be secured from the chairman, Professor Don E. Bloodgood, at Purdue University.

Announcement also has been made that copies of the "Proceedings of the Seventh Purdue Industrial Waste Conference" are available. Those who attended the Seventh Conference, held May 7–8, 1952, will receive a free copy of the 569-page "Proceedings," which includes a 20-page cumulative index for the first seven "Proceedings." For others the cost is $1.25 per copy. Checks should be made out to Purdue University and sent to Dean A. A. Potter, Schools of Engineering, Purdue University, Lafayette, Ind.

WHITE WATER TREATMENT *

VI. The Activated Sludge Process

By Willem Rudolfs and Herman R. Amberg

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The activated sludge process has, as yet, found only limited application in the treatment of soluble organic wastes high in B.O.D. Sludge bulking, low volume loadings, the nature of some wastes which constitute a specialized or incomplete food for microorganisms, and the possible presence of toxic substances have probably been factors in the resultant failure of the process to treat these strong organic wastes.

To determine the feasibility of the treatment of white water concentrate by the activated sludge process, the effects of load and mixed liquor sludge concentration were studied with special emphasis on sludge accumulation, rate of oxidation, rate of purification, and sludge characteristics.

Materials and Methods

The activated sludge used for these studies was obtained from a nearby sewage treatment plant. It was acclimatized to white water concentrate for 10 days prior to its use.

Rates of oxidation were determined by manometric measurement of oxygen utilization in the Warburg apparatus at 20° C. Rates of purification were measured by determining residual B.O.D. by the dilution method on supernatant from the mixed liquor samples at given time intervals. By this method, it was possible to distinguish between removal of B.O.D.—contrib-

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

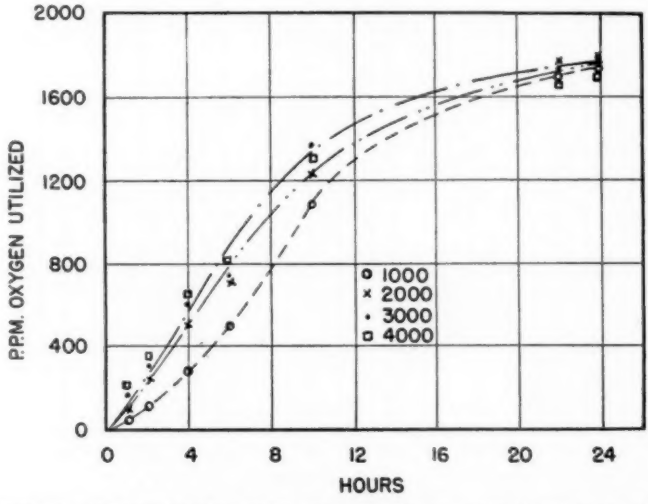

FIGURE 1.—Effect of sludge solids concentration on rates of oxidation of waste containing 2,000 p.p.m. B.O.D.

uting materials from the mixed liquor by the activated sludge and the oxidation of these materials on the sludge surface.

Samples were prepared containing mixed liquor, consisting of the desired waste and sludge concentrations, and distilled water if necessary. They were agitated on a shaker in a 20° C. incubator at 240 oscillations per minute continuously, except for the short time intervals required for settling the sample to remove supernatant for B.O.D. measurement.

Four suspended solids concentrations —1,000, 2,000, 3,000, and 4,000 p.p.m. —were used for all experiments, and the wastes used contained 2,000, 2,500, and 4,330 p.p.m. B.O.D. Each waste concentration was run for one week prior to the determination of the oxidation and purification rate curves. Aliquots of the sludge samples containing distilled water and the various sludge concentrations were placed in Warburg flasks to measure oxidation rates of the sludge, so that the oxidation at any time interval could be corrected for the added sludge, and oxidation values represent only that amount exerted by the added waste.

After 22 hr. of aeration with continuous shaking, the samples were allowed to settle and the sludge volumes were recorded after 0.5 hr. of settling. Suspended solids were determined (2-hr. settling) to obtain the initial sludge concentration desired.

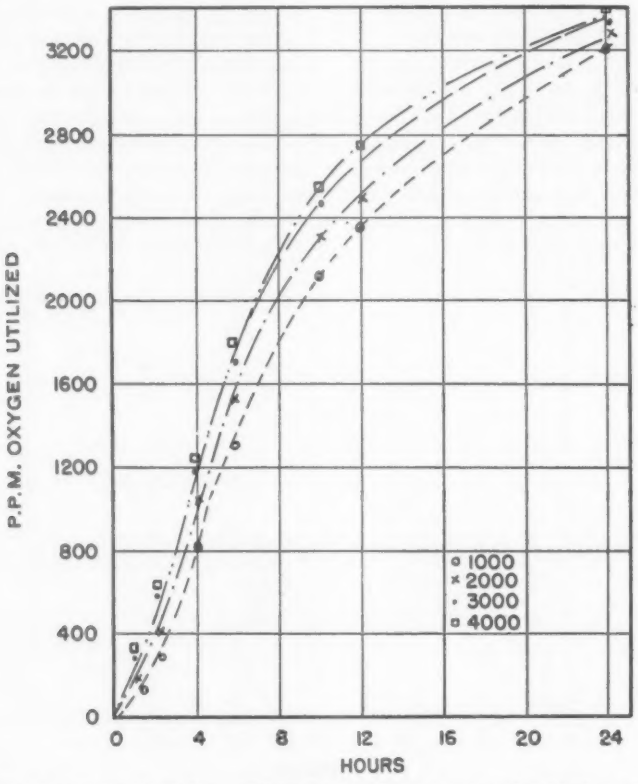

FIGURE 2.—Effect of sludge solids concentration on rates of oxidation of waste with 4,330 p.p.m. B.O.D.

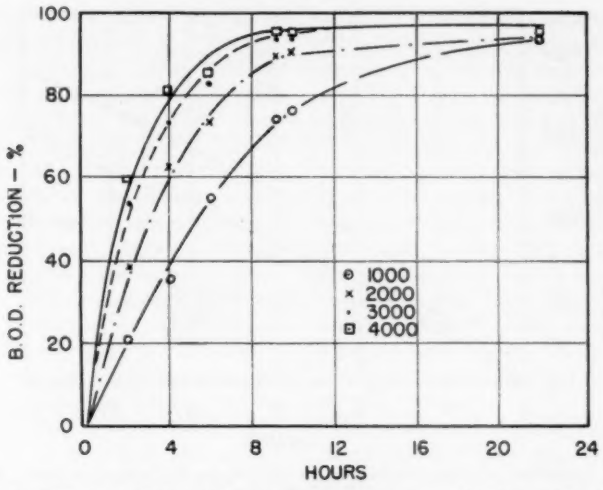

FIGURE 3.—Effect of sludge solids concentration on purification rates of waste with 2,000 p.p.m. B.O.D.

The white water concentrate was settled prior to the aeration, and ammonium nitrate and diammonium acid phosphate were added to the raw waste to satisfy the nitrogen and phosphorus requirements (B.O.D./N = 20; B.O.D./P = 40). The waste was concentrated to 6,000 p.p.m. B.O.D. and diluted, if necessary, to give the proper mixed liquor B.O.D.

Oxidation rates obtained (corrected for oxygen demand of the sludge) showed that oxidation approached completion in 12 to 16 hr. at all applied B.O.D. loadings. This is illustrated in Figures 1 and 2 for the lowest and

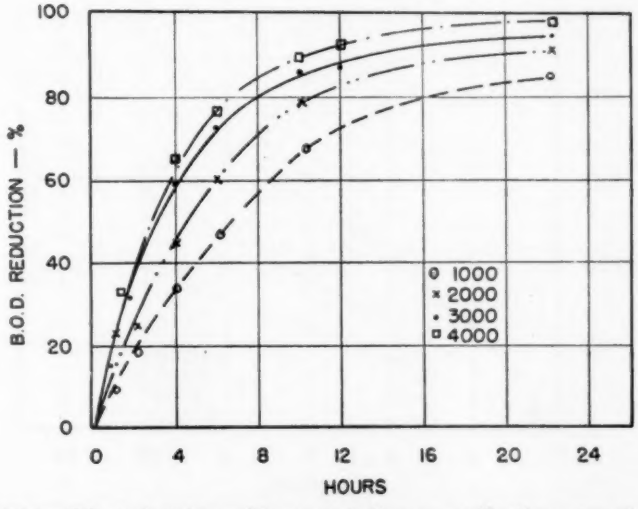

FIGURE 4.—Effect of sludge solids concentration on purification rates of waste with 4,330 p.p.m. B.O.D.

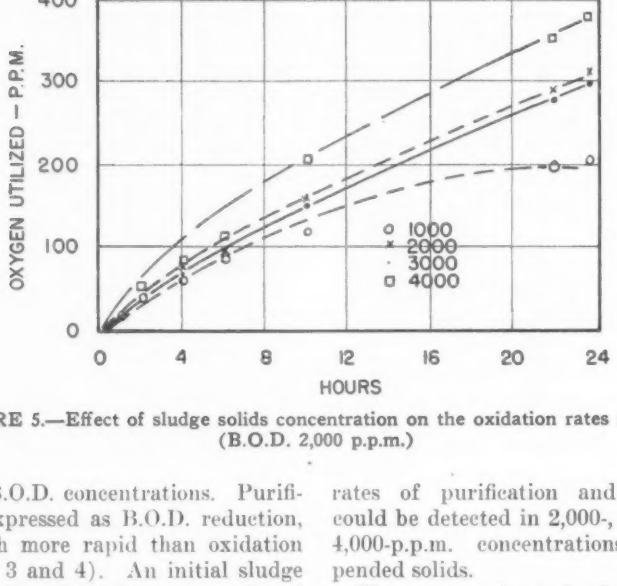

FIGURE 5.—Effect of sludge solids concentration on the oxidation rates of sludge (B.O.D. 2,000 p.p.m.)

highest B.O.D. concentrations. Purification, expressed as B.O.D. reduction, was much more rapid than oxidation (Figures 3 and 4). An initial sludge concentration of 1,000 p.p.m. was found to be inferior to the higher sludge concentrations, but little difference in the rates of purification and oxidation could be detected in 2,000-, 3,000-, and 4,000-p.p.m. concentrations of suspended solids.

The oxygen demand of the sludge as determined by the Warburg apparatus was not proportional to the sludge

FIGURE 6.—Effect of sludge solids concentration on the oxidation rates of sludge (B.O.D. 4,330 p.p.m.)

concentration in the mixed liquor, as shown by Figures 5 and 6. The differences in the oxygen demands of the various sludge concentrations became more pronounced as the B.O.D. load was increased, and at a B.O.D. concentration of 4,330 p.p.m. the oxygen demand of the sludge was almost proportional to the sludge concentration.

The relationships between sludge concentration and time required to effect a given degree of purification are illustrated in Figure 7. The time required for 90 per cent purification at the highest loading was reduced to one-half by increasing the sludge concentration from 1,000 to about 4,000 p.p.m.

The effects of time and sludge concentration on the oxidation rates corrected for the oxygen demand of the sludge (Figure 8) show that 90 per cent oxidation (expressed as a percentage of the 24-hr. demand when carrying 4,000 p.p.m. suspended solids) was accomplished in approximately 16 hr. with sludge concentrations of 3,000 and 4,000 p.p.m. At a B.O.D. loading of 294 lb. per day per 1,000 cu. ft. of aeration capacity, approximately 22 hr. of aeration would be required for 90 per cent oxidation, indicating that the maximum loading had been reached for the suspended solids concentration of 1,000 p.p.m. It appears that with sludge concentration of 3,000 and 4,000 p.p.m. much higher loadings can be handled without apparent deterioration of the process.

The average total and volatile solids accumulated at the various loadings are given in Table I. The percentage volatile solids increased at a B.O.D. loading of 500 g. per day, but decreased again when the load was increased to

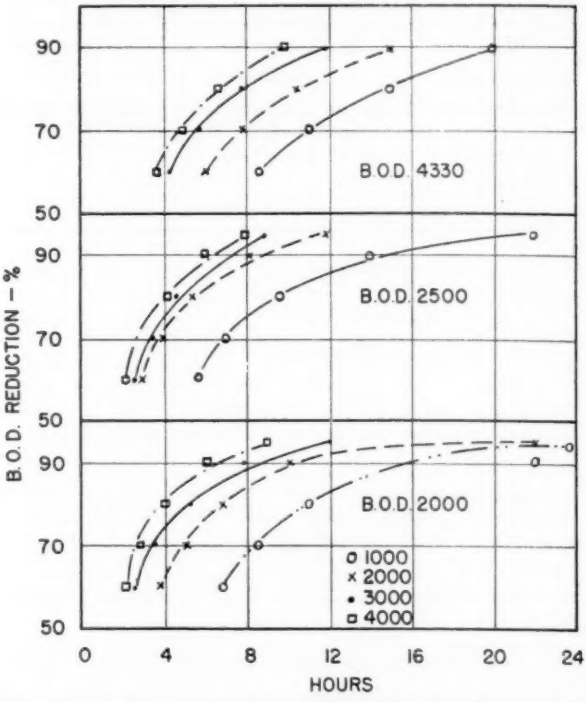

FIGURE 7.—Effect of time and sludge concentration on B.O.D. reduction of white water sludge.

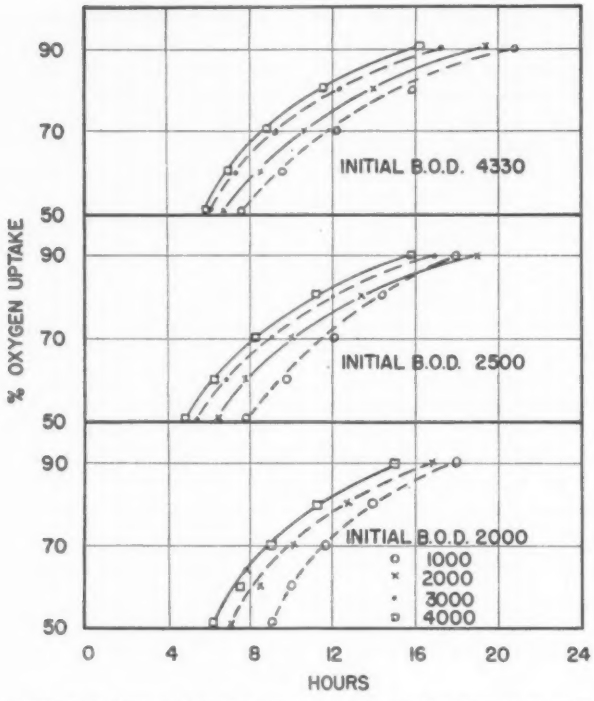

FIGURE 8.—Effect of time and sludge concentration on the degree of oxidation of white water sludge.

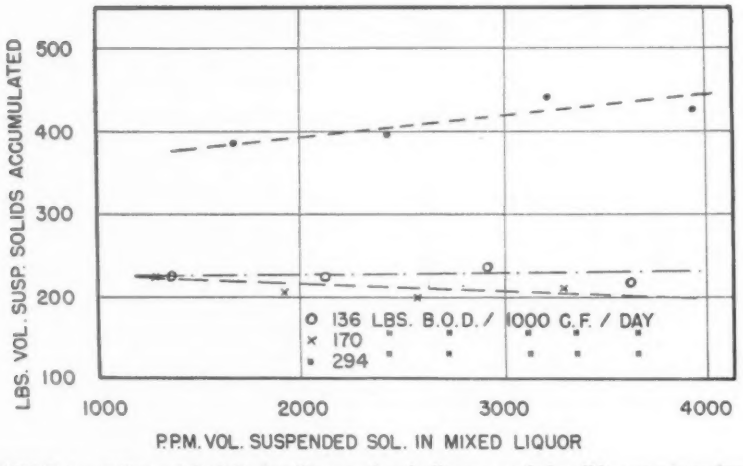

FIGURE 9.—Effect of B.O.D. loadings and volatile suspended solids concentration on sludge accumulation.

TABLE I.—Average Total and Volatile Solids Accumulated

Sludge at Start (g.)	B.O.D. Added (g./day)	Solids		
		Tot. (g.)	Volatile	
			(%)	(g.)
200	400	309	72.7	224
	500	276	80.9	223
	867	545	70.6	385
400	400	292	70.5	206
	500	286	78.1	224
	867	564	70.6	398
600	400	290	68.7	199
	500	305	77.4	236
	867	637	70.0	445
800	400	308	68.4	211
	500	286	76.0	217
	867	599	71.3	427

867 g. B.O.D. per day. Figure 9 shows that at B.O.D. loadings of 136 and 170 lb. per day per 1,000 cu. ft. of aeration capacity, the volatile solids (sludge) accumulated were not affected by the suspended solids concentration in the mixed liquor, but at a loading of 294 lb. of B.O.D. per day per 1,000 cu. ft. of aeration capacity a slight increase in solids accumulation occurred as the sludge concentration in the mixed liquor was increased from 1,000 to 4,000 p.p.m. The sludge accumulation plotted as a function of the B.O.D. load (Figure 10) indicates that the accumulation of sludge is a straight-line function of the applied B.O.D. load.

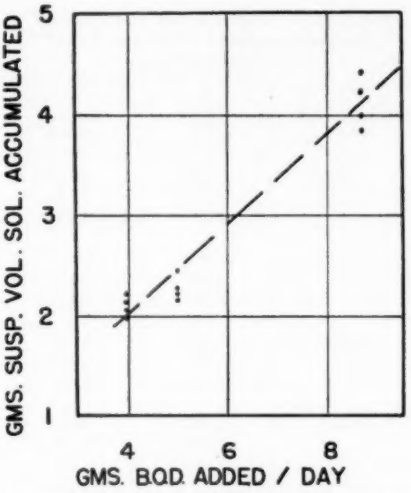

FIGURE 10.—Relation between B.O.D. loadings and volatile solids accumulation.

TABLE II.—Average Total and Volatile Solids Carried in Mixed Liquor

Susp. Sol.[1] (p.p.m.)	B.O.D. Added (p.p.m.)	Tot. Sol. (p.p.m.)	Vol. Sol. (p.p.m.)
1,000	2,000	1,780	1,295
	2,500	1,690	1,368
	4,330	2,380	1,680
2,000	2,000	2,740	1,930
	2,500	2,720	2,120
	4,330	3,420	2,420
3,000	2,000	3,740	2,570
	2,500	3,760	2,910
	4,330	4,580	3,210
4,000	2,000	4,790	3,280
	2,500	4,730	3,600
	4,330	5,510	3,920

[1] Starting concentration.

The average total and volatile solids carried in the mixed liquor (Table II) show that the average total solids carried in the mixed liquor were considerably higher than the starting concentration.

The accumulation of volatile solids (Table III) shows that approximately 500 lb. of volatile suspended solids were produced per 1,000 lb. of B.O.D. added. The sludge produced settled readily in 30 min. The sludge characteristics are indicated in Table IV. The sludge concentration decreased slightly at a B.O.D. concentration of 2,500 p.p.m., but increased again at the higher B.O.D. loading. The sludge volume index (Table IV) was under 50, and the average value at the upper B.O.D. loading was 30, irrespective of the sludge concentration carried in the mixed liquor.

TABLE III.—Volatile Solids Accumulated at Various Suspended Solids and B.O.D. Concentrations

Susp. Sol.[1] (p.p.m.)	B.O.D. Added (p.p.m.)	Vol. Sol. Accum.[2]
1,000	2,000	0.560
	2,500	0.446
	4,330	0.444
2,000	2,000	0.514
	2,500	0.448
	4,330	0.459
3,000	2,000	0.497
	2,500	0.472
	4,330	0.513
4,000	2,000	0.528
	2,500	0.434
	4,330	0.493

[1] Starting concentration.
[2] Pounds per pound of B.O.D. added.

The average B.O.D. reduction at the end of 22 hr. of aeration showed no significant difference at sludge concentrations of 2,000, 3,000, and 4,000 p.p.m. as the B.O.D. load was increased. At a sludge concentration of 1,000 p.p.m. a decrease in efficiency occurred when the B.O.D. load was increased from 170 to 294 lb. per day per 1,000 cu. ft. of aeration capacity. At the higher sludge concentration, the average B.O.D. reduction was about 95 per cent after 22 hr. of aeration.

TABLE IV.—Sludge Concentration and Sludge Volume Index

Susp. Sol.[1] (p.p.m.)	B.O.D. Added (p.p.m.)	Sol. Conc. (%)	Sludge Volume Index
1,000	2,000	3.08	32.4
	2,500	1.93	51.9
	4,330	3.24	30.8
2,000	2,000	3.28	30.5
	2,500	2.46	40.6
	4,330	3.14	31.8
3,000	2,000	3.5	28.6
	2,500	2.7	37.0
	4,330	3.4	29.4
4,000	2,000	3.6	27.7
	2,500	2.9	34.6
	4,330	3.3	30.3

[1] Starting concentration.

Discussion

The results show that white water concentrated to 4,330 p.p.m. B.O.D. was amenable to treatment by the activated sludge process. A B.O.D. load of 300 lb. per 1,000 cu. ft. of aeration capacity per day is by no means the upper loading limit, as indicated by the oxidation and purification rates. Carrying sludge concentrations of 3,000 and 4,000 p.p.m. in the mixed liquor, from 95 to 97 per cent of the B.O.D. was reduced after 22 hr. of aeration, whereas B.O.D. loadings varying from 136 to 294 lb. per day per 1,000 cu. ft. of aeration capacity had no noticeable effect on purification.

Settling of the mixed liquor for 30 min. after 22 hr. of aeration resulted in a dense sludge having a solids concentration of 3.0 per cent and a low sludge volume index. A sludge accumulation of 500 lb. of volatile solids and 700 lb. of total solids per day can be expected per 1,000 lb. of B.O.D. added. Assuming a 3 per cent sludge concentration, 375 cu. ft. of sludge would be produced per 1,000 lb. of B.O.D. added.

The increase in the quantity of the sludge is the result of a combination of the following factors:

1. Adsorption in the floc of resistant organic as well as inorganic materials.
2. Residual oxidizable organic material which has been adsorbed, but not oxidized.
3. Increase in bacterial protoplasm resulting from oxidation of the available food material.

Purification was much faster than oxidation, indicating that a considerable amount of the organic load is readily adsorbed on the floc but oxidized over a longer period. The activated sludge had an oxygen demand after 22 hr. of aeration, but carrying the oxidation nearer to completion would be

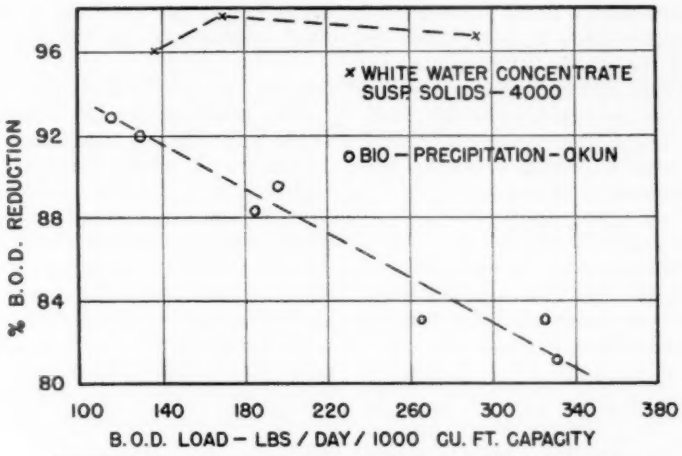

FIGURE 11.—Relation between loading and B.O.D. reduction.

deleterious because of reduction in floc size and production of an inert material with less adsorptive capacity.

Sludge accumulation from white water concentrate is directly related to the B.O.D. load, the sludge accumulation increasing as a linear function of the B.O.D. load. Heukelekian *et al.* (1), working with sewage at much lower loadings than those used in this study, found the sludge accumulation plotted as the volatile suspended solids accumulated per unit B.O.D. fed against the quantity of mixed liquor volatile suspended solids per unit amount of B.O.D. fed to have a linear relation. The experimental results obtained from white water concentrate, although scattered, fell between the two lines representing Heukelekian's results. The values he obtained may be extrapolated toward the ordinate with considerable reliability, which makes their work and conclusions valid for the treatment of strong organic wastes. The results obtained in the study reported here also indicate that the loading may be increased greatly, provided the air supply and the microbial population are sufficient.

Air or oxygen supply is the limiting factor in these complex relationships. As the sludge becomes less oxidized, as a result of improper balance between food and the organisms, it exerts a greater oxygen demand, which cannot be satisfied by the normal supply of air. With sufficient amounts of oxygen and organisms, the B.O.D. loading which can be applied to an activated sludge unit is theoretically unlimited, hence the use of oxygen in place of air should be a definite improvement over existing methods of aeration. A comparison of the results obtained by Okun (2) from the treatment of sewage by activated sludge using pure oxygen and those obtained with concentrated white water sludge shows that the purification results obtained from white water concentrate were somewhat higher for equivalent B.O.D. loadings (Figure 11). The lower efficiencies obtained for sewage are probably caused by the much shorter detention periods compared with the white water concentrate.

Even at B.O.D loadings of 294 lb. per day per 1,000 cu. ft. of aeration capacity, sludge bulking was not encountered at any of the suspended solids concentrations. It becomes evident that one of the more important factors in sludge bulking is caused by oxygen deficiencies and that much higher loadings can be applied if the oxygen sup-

ply is sufficient. It is possible that with improvements in equipment design and the use of pure oxygen, extremely high B.O.D. loadings could be handled by the activated sludge process and that a large number of strong soluble organic wastes could be efficiently treated by this process.

Conclusions

From the experimental data obtained and from calculations and comparisons, the following general and specific conclusions have been drawn:

1. White water concentrate is amenable to treatment by the activated sludge process. When sludge concentrations of 3,000 and 4,000 p.p.m. are carried in the mixed liquor, 97 per cent of the B.O.D. can be reduced after 22 hr. of aeration at a B.O.D. load of nearly 300 lb. per 1,000 cu. ft. of aeration capacity per day.

2. The sludge produced settles readily in 30 min. It has a solids concentration of 3.0 per cent and a sludge volume index of less than 50.

3. Sludge accumulation of about 500 lb. of volatile and 700 lb. of total solids (day basis) can be expected per 1,000 lb. of B.O.D. added, or a sludge volume of approximately 375 cu. ft.

4. Sludge accumulation appears to be a linear function of the B.O.D. load, bearing no relationship to the suspended solids concentration within the narrow loading limits studied.

5. In presence of sufficient oxygen, a well-oxidized sludge having a volatile solids concentration of 70 per cent can be expected. With proper air supply, B.O.D. loadings of 300 lb. per 1,000 cu. ft. of aeration capacity per day will not cause bulking.

6. Oxidation and purification rates indicate that loadings in excess of 300 lb. of B.O.D. per 1,000 cu. ft. of aeration capacity per day are possible.

Summary

The activated sludge process has found only limited application in the treatment of soluble organic wastes high in B.O.D. To determine the feasibility of the treatment of white water concentrate by the activated sludge process, the effects of load and of mixed liquor sludge concentration were studied with special emphasis on sludge accumulation, rate of oxidation and purification, and sludge characteristics. The laboratory studies were conducted at 20° C. with continuous shaking for 22 hr.

White water concentrate up to a B.O.D. concentration of 4,300 p.p.m. is amenable to treatment by the activated sludge process and about 96 per cent of the applied B.O.D. can be reduced in 22 hr. at a B.O.D. loading of nearly 300 lb. per day per 1,000 cu. ft. of aeration capacity. Sludge accumulation was found to be a function of the B.O.D. loading. Approximately 700 lb. of dry sludge can be expected per 1,000 lb. of B.O.D. added, or about 375 cu. ft. of 3 per cent sludge.

Acknowledgment

Studies reported in these papers were conducted under a grant from the National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries).

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BIOCHEMICAL OXIDATION OF DAIRY WASTES
V. A Review*

By Sam R. Hoover

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In response to the requests of many members of the dairy industry, the U. S. Department of Agriculture decided in 1947 to initiate research on new and cheaper methods of treating the processing wastes from this important industry. This paper reviews the progress made, with especial attention to the possible application of the results in treating municipal sewage.

The research undertaken was decided upon after consultation with the Task Committee on Dairy Waste Disposal of the Dairy Industry Committee. The research subcommittee of this group, composed of H. A. Trebler of National Dairy Research Laboratory; M. D. Sanders of Swift and Co.; and A. J. Steffen, Chairman, of Wilson and Co., has been especially valuable because of their advice and encouragement. The following six points are quoted from the notes of a meeting on August 12, 1947, when Dr. Trebler came to the laboratory and stated what he thought were the problems to be studied:

"1. Is the 50 per cent reduction in B.O.D. obtained by 24-hr. aeration of milk wastes a chemical or biochemical process?

"2. Can a rapid aerobic fermentation be developed?

"3. Could the Dow aerobic process (used on chemical process wastes) be adapted to milk wastes?

"4. What is the B.O.D. of the various constitutents of milk, and in what order are they oxidized?

"5. A chemical test for B.O.D. would be of great value. This has been tried before, but with limited success.

"6. Development of a non-plugging aeration system would be an immediate contribution."

It is believed that answers to the first five problems are at hand. Considerable additional information has been obtained and a number of studies are under way which could not have been predicted five years ago.

A 10-gal. fermenter or aerator with a mechanical impeller was used for studying the aeration process. The rate of feed, temperature, air flow, and agitation were closely controlled, so that a constant environment would be provided. Analyses of the influent and effluent were made for protein, lactose, and oxygen consumed by dichromate (O.C.). The O.C. test was extremely valuable. Its development and relation to other tests for oxygen demand are discussed later. With these tools, a start was made on answering the questions raised.

Biological Synthesis

A 50 per cent reduction in O.C. was obtained in numerous experiments, confirming previous results. Moreover, analytical tests showed that only one reaction was occurring:

$$\text{Milk solids} + O_2 \rightarrow \text{Bacterial cells} + CO_2 \quad (1)$$

There were essentially no by-products, neither were there unused casein

* Presented at 24th Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; August 27–29, 1952.

and lactose of milk. A biochemical reaction occurs in which the soluble milk constituents are converted to bacterial cells. The yield of cell substance was slightly more than 50 per cent (7). These results answered the first question; the reaction was a specific biochemical transformation of organic nutrients to cell material, or, more plainly, growth of cells.

Rapid Aerobic Fermentation

The development of a rapid aerobic fermentation on the basis of these results was next studied. It was shown that 1,000 p.p.m. of skim milk solids were completely converted to cells in 5 to 6 hr. (4). The rate of this reaction in a mixture containing 500 p.p.m. sludge solids was independent of the amount of milk solids above 100 p.p.m. and fell off markedly only below 50 p.p.m. The rate of oxidation was independent of oxygen tension above 0.5 p.p.m. Also, the rate of oxidation was found to be 0.4 p.p.m. O_2 per minute in one study and as high as 1 p.p.m. O_2 per minute in other experiments (8). Those familiar with the field can appreciate the engineering problems in dispersing air fast enough to supply 1 p.p.m. O_2 per minute.

The separation of the cells from the liquors by centrifuging left an effluent containing only about 10 per cent of the original chemical oxygen demand (7). There is recent evidence that this 10 per cent is primarily bacterial cells, for centrifugation at higher RCF results in a B.O.D. reduction of more than 95 per cent. These results were obtained in the laboratory aerator, which has vigorous mechanical action. The best means of aeration and of separation of the cells or sludge on a practical scale are major phases of the pilot plant work in progress at Pennsylvania State College by contract between the United States Department of Agriculture and the college.

Partial Treatment Process

Another possible way of using this aeration process was studied and recommended (6). It is simply aeration to bring about the conversion of milk solids to cells and the discharge of the aerated mixture without removal of the bacterial cells. Because of the lower rate of oxidation of the cells, or greater relative stability, as it is often called, the reduction in 5-day B.O.D. obtained is about 75 per cent. Such a partial treatment would have two possible applications. First, in many extremely small plants, or in larger ones where complete treatment is not required, it would substantially reduce pollution. Second, the effluent from this partial treatment would be amenable to treatment in a municipal sewage treatment plant. One such arrangement has been installed and is reported to work well. The dairy plant wastes enter the sewage treatment plant separately and are aerated in one tank, then flow into the second tank, where the municipal sewage enters; both are aerated there. The sludge is returned to the first tank.

It was proposed, also, that the aeration be on a fill-and-draw basis, with continuous aeration during the draw-off period, which would be during the night when domestic sewage flow is low. In this system the partly treated effluent would be discharged to the sewer system, and there would be no need for a separate line from the dairy plant to the treatment plant, an obvious impossibility in many cases.

These proposals are based on laboratory studies and cannot be considered fully developed treatment systems. They go a long way, however, toward answering the second question. The third one, consideration of the Dow process, is also answered in a general way. The essential features of the Dow process are the stimulation of a rapid bacterial action and the sweeping out of volatile organic matter, both

of which are accomplished by vigorous aeration. Only a small portion of the pollution in milk wastes is volatile, so the latter feature would be of no importance, but rapid biological oxidation, and even additional mechanical agitation, would certainly be advantageous.

Conversion to Cell Solids

A study of the rate and extent of oxidation of the skim milk solids by "activated sludge" was most enlightening (4) (8). Casein and lactose were found to be oxidized at the same rate. It was found that only 35 to 40 per cent of the oxygen required for the complete oxidation was consumed. The composition of the cells was determined and complete balanced chemical equations for the growth of the bacteria were worked out. Although these data were all obtained on the oxidation of milk solids, there is good reason to believe that the general principles hold for other industrial wastes and even for sewage. Bacteria have a relatively constant composition regardless of the source of nutrients. For example, the composition of the organisms recovered from the aeration of dairy waste (7) can be compared with that of the commercial sludge product prepared at the Milwaukee sewage treatment plant (11). The latter product is contaminated with sand, silt, and the iron added as a coagulant. When the analytical data are corrected for these contaminants, the composition of the Milwaukee product is seen to be about the same as that of the dairy waste organisms (Table I).

Another application of the equations developed is the calculation by Eckenfelder (12) of the theoretical amount of sludge produced by an experimental unit treating cannery wastes. He found the actual yield of sludge to be almost exactly that calculated from the data on dairy wastes. Also, preliminary calculations of sludge from sewage treatment indicate rather good agreement with the values predicted from the equations.

TABLE I.—Composition of Dairy Waste Sludge Compared with that of Milorganite

Constituent	Dairy Waste Sludge	Milorganite[1]
Protein (N × 6.25) (%)	67	65
Carbohydrate (%)	14	12
Fat (%)	—	11
Ash (%)	9	11

[1] Corrected for sand and silt (30.2 per cent), Fe_2O_3 (6.1 per cent), and water (6.2 per cent).

Endogenous Respiration

The idea that the primary biochemical reaction is assimilation or growth of cells has a corollary—the further oxidation of these cells by their own metabolism. In studies of bacterial metabolism, this is called endogenous respiration. The question naturally arises whether endogenous processes go on during the rapid growth process. Some years ago strong indirect evidence that it persisted during growth was presented for the symbiotic nitrogen-fixing bacterium, *Rhizobium meliloti* (3). Recently a demonstration that endogenous respiration of a streptomyces persists during growth was made by Cochrane and Gibbs (1). By use of radioactive carbon (C^{14}) they showed that the oxidation of cell carbon goes on unchanged while the cells are growing on unlabeled glucose. It is probable, therefore, that activated sludge maintains its endogenous respiration during growth.

Recently the rate of endogenous respiration for periods up to 48 hr. has been measured (5). The analytical composition of the sludge was found to be $C_5H_7NO_2$. This "formula" cannot be considered to represent any compound; it merely gives the proportion of the oxidizable elements to oxygen. The amount of sludge obtained by the volatile solids determination will have this composition. The endoge-

nous respiration proceeds according to the equation:

$$C_5H_7NO_2 + 5O_2 \rightarrow 5CO_2 + NH_3 + 2H_2O$$
$$113 + 160 \rightarrow 220 + 17 + 36$$

The oxidation of 1 lb. of sludge (volatile solids) requires 160/113 or 1.42 lb. of air. The rate of this oxidation is low; in different experiments it has ranged between 0.5 and 1.0 per cent of the cell tissue oxidized per hour.

Calculation of Solids Balance

From the equations established for the synthesis of cell tissue from milk solids, a yield of 226 units of cells from 424 units of lactose and protein was established, or 53.3 per cent yield of volatile solids. This value is equivalent to the previously reported 58.5 per cent, determined by dry weight, for the sludge containing 8 per cent ash. Thus, a waste containing 1,000 p.p.m. organic matter (not B.O.D.) would produce 533 p.p.m. sludge. The rate of endogenous respiration (or autodigestion) is, at a minium, 0.5 per cent per hour, or 12 per cent per day. If 2,500 p.p.m. sludge (volatile solids) are carried in this system, 300 p.p.m. will be oxidized daily, and sludge will accumulate at a rate of 233 p.p.m. daily. It is obvious that if the rate of endogenous respiration is higher, say 1 per cent per hour, the sludge produced will be completely oxidized and none will accumulate.

These examples are given in detail because a method for determining the rate of oxidation by sludge has recently been developed (10). It is a simple titrimetric measurement of the carbon dioxide produced by the oxidation. Such a determination should be of great use in both industrial waste and sewage treatment.

A number of research and operation control laboratories have requested the details of this method prior to publication. It is hoped that it will be used to measure the oxidative capacity of sludge in enough plants to verify in actual operation the concepts presented here. It would seem that such information would be of great value, both for control of existing plants and for assistance in designing future plants.

Parenthetically, it should be stated that other workers have presented somewhat similar ideas. Heukelekian and co-workers (2) recently developed an equation for the accumulation of sludge solids which has two major portions, a rapid production of sludge and a slow oxidation of it.

The results on the rate and extent of the biochemical reactions occurring in the aerobic oxidation of dairy waste and their possible application to sewage treatment have been discussed in as much detail as space permits, for, as stated in a recent review in THIS JOURNAL, these data and interpretations are probably the laboratory's greatest contribution to this subject to date. It is believed that the results have gone further than anticipated when the original request was made to study the oxidation of milk and its constituents.

Oxygen Consumed *vs.* B.O.D.

Finally, a "chemical test for B.O.D." was requested. This was one of the first problems investigated, for such a test was needed in the experimental work. After study of several alternatives, a simple oxygen consumed (O.C.) method developed by Eldridge was selected, and thousands of determinations have been made in the laboratory. A study was made of the variables in the test, and its applicability to various other wastes was demonstrated (9).

The exact correlation of B.O.D. and O.C. is difficult, if not impossible, for the B.O.D. is a complex of the amount of oxidizable material and its rate of oxidation, whereas O.C. measurements determine the amount of material oxidizable by dichromate under given conditions. For most organic materials, it approximates the 20-day B.O.D., if inhibition, nitrification, and other fac-

tors that influence the B.O.D. are ruled out. Cellulose, of course, is rapidly oxidized chemically and is relatively inert biologically.

The correlation between 5-day B.O.D. and O.C. must be attempted, despite the difficulty, for all legal aspects of pollution depend on the B.O.D. test. On theoretical grounds, the ratio B.O.D./O.C. of easily oxidizable milk solids should be higher than 0.68, and this ratio should be lower for the bacterial cells. As discovered previously, the latter are reluctant to oxidize their own tissue. These theoretical considerations have been verified in laboratory tests, but no satisfactory agreement is found in B.O.D. tests on similar samples taken at different times. However, a set of operating results obtained over a two-month period by the National Dairy Research Laboratories was received recently for analysis. Simultaneous analyses of the contents of an aeration tank were made by the two methods. The data are plotted in Figure 1. The line for the lower portion is drawn by allowing equal numbers of points on each side. It has a ratio of B.O.D./O.C. of 0.38, and two-thirds of the values lie within ± 20 per cent of this line.

There are not enough points above 500 p.p.m. O.C. to establish a good line. The dashed line has a slope of 0.8, which would be a reasonable ratio. A line fitted to the 16 points above 500 p.p.m. O.C. would have a slope of slightly greater than 1.0, which would not seem reasonable. It is apparent that more data of this type, obtained in the field, are required before the two methods can be correlated adequately. In the meantime, a value of 0.4 for the ratio of B.O.D./O.C. can be used as a first approximation for bacterial cells or activated sludge.

Volatile Solids of Sludge by O.C. Test

The O.C. method can be used also as a rapid method of determining the organic content or volatile solids of sludge. The empirical factor of 1.25 mg. O_2 per milligram of sludge was established previously for a sludge that had 8 per cent ash (4). If this value is corrected to a volatile solids content,

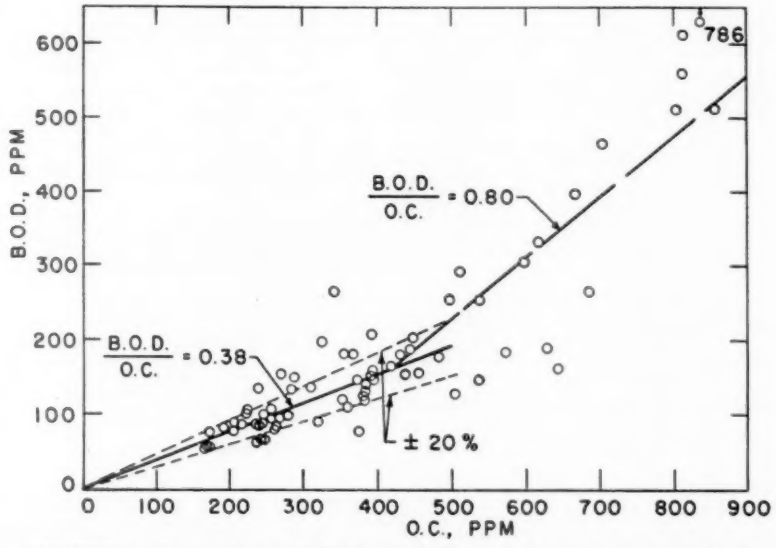

FIGURE 1.—Comparison of B.O.D. with O.C. determinations on contents of aeration tank.

the factor is 1.25/0.92, or 1.36 mg. O_2 per milligram of volatile solids. Eckenfelder (12) has confirmed this value; his determined factor is 1.33 mg. O_2 per milligram of volatile solids.

The sixth of the posed problems has not been studied in this laboratory. It is hoped that successful work on dispersion of air can be done in the pilot-plant studies at Pennsylvania State College. The problem is one for engineering research rather than for biochemical research, and it is believed that it can be investigated more satisfactorily in the pilot plant than in the laboratory. It is a difficult job, which many have attempted to solve.

Summary

Study of the aerobic oxidation of dairy wastes from the biochemical viewpoint has answered many puzzling questions. The essential features are bacterial growth and subsequent oxidation of these bacteria by their own metabolism (endogenous respiration). Therefore, the existing knowledge of bacterial metabolism can be brought to bear on the problem. The relationship between these studies and the oxidation of other industrial wastes and of sewage has been discussed.

Acknowledgment

The research reported in this and previous papers is the joint effort of Dr. Nandor Porges, Mrs. Janet B. Pepinsky, Miss Lenore Jasewicz, and the author. The advice and cooperation of the Task Committee on Dairy Waste Disposal of the Dairy Industry Committee have been valuable throughout.

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DISCUSSION

By F. B. Milligan

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The results and present conclusions of a great deal of careful work during the last five years are ably summed up in this paper. This work demonstrated, among a number of other things, that milk wastes could be oxidized in the laboratory, under controlled temperature, aeration, and flow, by aerobic fermentation using yeast cells; that one-half of the organic matter in the waste was oxidized by the microorganisms; and that most of the remainder was assimiliated into the cell tissues. The oxidation of the organic matter provided energy for the cell growth.

The work further showed that by continued addition of air, these cells are oxidized by their own metabolism (that is, by the chemical changes under which energy is provided for the vital processes and new material is assimilated to repair the waste) to ammonia, carbon dioxide, and water. This process is termed "endogenous respiration," a biochemical term stated by Dr. Hoover to mean that each cell can subsist on its own tissue, using its own oxygen supply almost entirely.

This elimination of sludge is a logical explanation of observed and reported occurrences at a number of milk plants using the activated sludge process.

Inasmuch as the processes discussed are to be further developed at the Pennsylvania State College through pilot-plant studies, it is decidedly of interest to know that the best means of aeration and of separation of the cells or sludge from the treated effluent on a practical scale are considered major phases of the work.

Under this project, studies of the methods of treatment developed by Dr. Hoover and his associates are contemplated using a full-scale milk waste treatment plant on a fishing stream in central Pennsylvania. As a part of these studies, it is planned to discharge directly to the stream the suspended solids resulting from the conversion of the milk solids to cells. If this is done it will be possible to determine, among other things, (a) the effect of these cells upon the receiving stream as to its oxygen content, suspended and dissolved solids, turbidity, color, and the deposition of solids; (b) the appearance and character of the effluent itself; and (c) the advantage of the aerobic fermentation process over the conventional activated sludge process.

The reference just made to the effect of the discharge of cells on the receiving stream is due in part to Dr. Hoover's statement that "the yield of cell substances was slightly over 50 per cent" and that "the further oxidation of these cells (is) by their own metabolism" ("endogenus respiration"). I understand that such cells seem to have a very low B.O.D.

If the cells formed by the initial oxidation reaction require oxygen for conversion to harmless end products, then if such cells are discharged to the stream is it not true that they must either exert a demand on the stream for oxygen, or if this is prevented by the dispersion of the cells or the lack of other assimilable material in the stream water, then must not such cells be carried along, adding their bit to the suspended solids load of the stream, unless finally deposited on the banks and bottom? If these are living cells, what happens when they die?

Many types of partly stabilized sludges, discharged to the stream in small quantities, might serve as fish food or be difficult or impossible to detect as sludge deposits. But a large discharge from a big plant on a small stream would pose a different problem.

This is a matter which must be

gravely considered, as it may affect the Pennsylvania Sanitary Water Board's fundamental policy requiring a uniform degree of treatment by each contributor to the pollution of a given stream.

DISCUSSION

By C. L. Siebert, Jr.

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In previous papers, Dr. Hoover has presented results of laboratory experiments in aeration upon a synthetic waste made of skim milk solids, and related the results by means of chemical formulas to show (a) the empirical composition of the bacterial cell structure and (b) the oxidation reactions as they appear to occur upon actual lactose and casein to form bacterial cell structure of the composition $C_5H_7NO_2$. The release of ammonia by the reaction upon casein and the requirement of ammonia for the reaction upon lactose, which two constituents are present in more or less equal parts in skim milk, appears to explain satisfactorily the resultant small change in pH which occurs during the oxidation reaction.

There appears to be evidence, from a series of experiments performed at the Department of Agriculture laboratory and elsewhere, that the bacterial cells formed by the initial oxidation reaction can and do subsist upon themselves, forming as end products carbon dioxide, ammonia, and water. These observations would appear to serve as a good foundation upon which to base the phenomenon of actual milk waste treatment works operating without an apparent formation of sludge in quantities that require the provision of plant units to take care of the accumulation.

The position of the Pennsylvania Department of Health in this respect is that adequate proof has not yet been presented by the limited number of aeration process milk treatment plants now in operation in Pennsylvania, to establish beyond all doubt that sludge handling facilities are entirely unnecessary. The Department has, however, recommended to the Sanitary Water Board the approval of plans for a considerable number of aeration process plants, which plans do not incorporate sludge storage tanks, digesters, or sand beds. There is reasonable optimism that in actual practice digesters or sand beds can be omitted at most, if not all, classes of installations. It appears as a definite possibility, however, that some such features may be desirable when dealing with wastes from dairies performing certain manufacturing operations, or where the raw wastes are especially concentrated.

With only two exceptions, all of the dairy waste treatment plants where extensive field surveys have been made by Pennsylvania Department of Health personnel, have employed one of several types of diffusers for introducing air into the mixed liquor. From observations of operating experience, it appears that all types of such diffusers leave something to be desired. Those types which are most efficient in breaking up air in order to obtain reasonable efficiency, are subject to clogging at far too frequent intervals. The simplest form of diffuser, if it can be called that, is a perforated pipe, which is satisfactory from an operating standpoint but is wasteful of air and may possibly create too violent an agitation, if overagitation is conceivable. Only one plant surveyed used any of the several jet aeration systems available; at that plant loading was so light that a significant comparison could not be made

with the other plants. The remaining plant employed splashplate recirculation.

It is understood that there is a likelihood of installation of jet-type aerators at several plants in Pennsylvania in the near future, at locations where loading and general plant design should be sufficiently typical to permit comparison with diffuser-equipped plants.

Experience has indicated that even where it is possible to control the suspended solids in the mixed liquor by drawing off sludge to a digester, it is not desirable to maintain particularly low concentrations, because under such conditions the plant appears less able to handle sudden overloads which may be imposed upon it. A concentration of 4,000 to 5,000 p.p.m. of suspended solids in the mixed liquor appears to represent good operating practice.

One feature which appears to have been evaluated not too well in a number of plant designs is the difficult settling characteristic of the suspended solids in the mixed liquor. Experience to date leads to the rather firm belief that in order to obtain an effluent substantially free of suspended solids, a detention period approaching 3 hr. must be provided in the settling tank. Moreover, a settling tank underflow return rate of 4 to 5 times the equalized 24-hr. flow rate through the plant should be employed. In the establishment of settling detention period under these conditions, only the average weir discharge rate should be used, thereby eliminating the need for a larger tank by reason of the high sludge return rate.

Regarding the greater relative stability of the bacterial cells than of the milk solids in a raw waste, observations in this direction have been made by at least one field worker of the Department. In an aeration process milk treatment plant of typical modern design, it became necessary to discharge effluent at a higher than normal rate for a period of time, in order to unload an excessive amount of liquid that had been accumulated in the holding and equalizing tank. The high rate of discharge through the settling tank unit caused a carryover of an abnormally high amount of solids, as could be expected. The suspended solids concentration in the effluent sample was slightly higher than in the corresponding raw wastes sample, but a B.O.D. reduction of 90 per cent was found. It is believed that these results indicate the formation of relatively stable bacterial cell solids in place of the original lactose and casein.

It is hoped that more can be learned about the stability of these cell solids and their effect upon the receiving stream by a project now contemplated by Dr. Hoover's laboratory in conjunction with the Pennsylvania State College.

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Stream Pollution

AQUATIC ORGANISMS AS AN AID IN SOLVING WASTE DISPOSAL PROBLEMS *

By Ruth Patrick

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This paper discusses the various ways in which aquatic organisms may be of use in solving problems associated with waste disposal. Since many state and federal laws set forth that nothing may be discharged that is deleterious to aquatic life, the most expedient way to determine the effect of an effluent is to study the aquatic organisms themselves.

In every river that has not been adversely affected by pollution there is a great variety of aquatic life. These organisms do not represent a great mass of living things, but rather they are organized into an intricately balanced system, often referred to as a food chain of biodynamic cycles.

Bases of Food Chain

At the base of the food chain are the bacteria. These organisms use the complex wastes entering a river as a source of energy in their metabolism. In so doing they break down the wastes into substances that can be used as a source of food by other organisms. These processes, which are often referred to as decay or decomposition, occur most rapidly when the bacterial population is of optimum size. When the bacteria become too numerous the processes are slowed down. The protozoa and other small invertebrates which feed on bacteria are instrumental in keeping the bacterial populations in check.

The algae are also at the base of the food chain. They are able to utilize inorganic substances to make proteins and carbohydrates, which are used as a source of food by other organisms. Indeed algae have often been referred to as the grasses of the sea. Upon them not only the many different invertebrates, but also some fish and other vertebrates, feed directly. Besides their value as a source of food they also replenish the oxygen supply of a river by a process known as photosynthesis. This is the method by which carbohydrates are synthesized and oxygen is given off as a by-product. Indeed, in many rivers this is the principal way in which oxygen is restored after it has been depleted.

The algae and the bacteria are the most important organisms in bringing about the "rejuvenation" or "cleansing" of a river. The roll of the fungi is also significant in this respect, but as yet not as well understood.

Many Food Chains Involved

As previously stated, many invertebrates, such as the worms, the snails, and the insects, feed directly on the bacteria, the fungi, and the algae. They in turn are a source of food for the carnivorous species; thus, a closely integrated food chain is formed.

This food chain does not consist, however, of a single series of links, but rather of a series of chains that are sometimes interlinked. Thus, pollution may break one series of links, yet

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not completely destroy the chain. It is only when pollution is extreme that the chain is completely broken and the higher forms of life are completely eliminated. Thus, when one is concerned with the problems of waste disposal and river conservation, he must concern himself with the whole pattern of life in the river rather than just one group; for example, the fish.

Pollution Effects

There are commonly five ways in which wastes may harm the aquatic life of a river, as follows:

1. They may produce oxygen deficiency. This may be due to the bacteria, which attack the wastes and use oxygen in their metabolic processes. The wastes also may not be completely oxidized when they are discharged and thus take up oxygen from the water in completing the oxidation necessary to stabilize them.

2. They may be toxic to aquatic life. This may be due to the nature of the chemicals themselves. However, it may be due to the pH which they create in the river. Wastes also may be toxic due to the osmotic pressure which they develop in river water, thus bringing about conditions unfavorable for aquatic life.

3. Temperature changes produced by wastes may be harmful in two ways. The amount of change which they produce may be deleterious. It is a well-known fact that a sudden change in temperature of more than two degrees is harmful to the sunfish. Also, a waste, by raising or lowering the temperature of a river only two degrees, may cause the temperature of the water to be in a critical range deleterious to the functioning of certain physiological processes necessary for life.

4. The physical properties of the wastes may be harmful. They may carry suspended solids that are abrasive and thus injure mechanically the membrane of the gills of fish. In other cases, such as oil, they may coat the gill structures and thus make the absorption of oxygen from the water impossible.

5. Wastes may render the habitats of aquatic organisms untenable. For instance, suspended solids may settle out and clog up the natural habitats of aquatic organisms. Eggs may become buried. In other cases the added pressure created by settleable solids may cause the egg cases to burst. Some wastes produce turbidity, thus hindering light penetration. Thus, the photosynthetic zone of a river will be greatly restricted and the algal production limited.

Besides bringing about death of organisms, waste may lower their resistance to the normal factors in the environment so that eventually the population dies out. To date these effects of wastes have been studied very little.

The Academy of Natural Sciences of Philadelphia has used two approaches to study the effect of pollution on a river—laboratory tests and river surveys.

Laboratory Tests

For determining the oxygen consumption of a waste, a combination of tests are used: immediate oxygen demand, biochemical oxygen demand, and complete oxygen demand. These tests are well described in the literature.

The methods for determining the toxic effects of wastes on aquatic life have, to a great extent, been developed in the Academy laboratory. A considerable part of this work was done with the aid of a grant from the American Petroleum Institute.

Realizing the importance of the biodynamic cycle, the effect of a given waste is determined by using organisms representing three stages in the cycle. These organisms are as follows:

1. An alga that is important as a producer of oxygen, and as an organism that can convert inorganic substances into a direct source of food for many aquatic animals.

2. An invertebrate that serves as a direct food for fish. As representatives of this group, insects and snails have been used.

3. Fish, because of their recreational and economic importance.

The fish tests are conducted according to the methodology set forth by the Federation's Subcommittee on Toxicity (1).

Insect and Snail Tests

The insect and snail tests have been patterned after the fish tests. As with the fish, care is taken to assure that the organisms are thoroughly acclimated to laboratory conditions. This is determined by a very low death rate and by the fact that growth is taking place in the acclimatization tank over a period of time. This takes several weeks, and sometimes months, to ascertain. The invertebrate tests are conducted under constant temperature and dissolved oxygen conditions. A constant volume of fluid to organism is maintained. The organisms are not fed during the test. As in fish, death is a difficult condition to establish. It is defined as lack of response to tactile stimulus and failure to recover. This is accompanied by various changes in the appearance of the organisms. In insects the same procedures as those used with fish are followed. In the case of snails, after they fail to respond to tactile stimuli, they are placed in uncontaminated water in which they have been reared. If they do not recover in 48 hr., they are determined to be dead.

Algae Tests

The algae tests, although similar fundamentally, are quite different from the fish or insect tests. For these tests the diatom *Nitzschia linearis* was chosen. This diatom is commonly found in eutrophic streams and rivers which have not been adversely affected by pollution in the eastern and midwestern sections of the United States. The tests are conducted in Erlenmeyer flasks. The light source is artificial, being a combination of neon and "daylight" fluorescent lights. The tests are usually conducted at 18° to 20° C., depending on the temperature of the water into which the waste being tested will be discharged. The dilution water, as in the case of the fish, is a natural water or a synthetic water, which has been selected because it matches in chemical composition the water of the river into which the waste will be discharged.

The diatom cultures used in these tests consist of a single species of algae. They are cultured in the laboratory several months before testing, and are known to be maintaining a division rate characteristic of healthy diatoms of this species. Since death is a difficult thing to determine in a diatom, the point at which the growth rate is decreased 50 per cent below that of the control is taken as comparable with the median tolerance limit obtained in fish tests.

In the course of experimentation it has been found that the rate of growth is influenced by the size of the inoculum. Therefore, it is necessary that the same size inoculum be used in the control as in the tests. This is verified by counting the number of cells per milliliter in each flask at the beginning of the experiment. All tests, as well as the control, are run in duplicate. All subsequent counts are made in the same manner as at the beginning of the test to determine the rate of growth.

The duration of the test should be from 5 to 7 days. Often, at the beginning of an experiment, there is a "lag" effect before the diatoms respond to the test medium. This effect may last for 48 hr. From the third to the seventh day is the time when the growth rate can be most accurately correlated with the effects of the test medium. After this length of time some of the necessary nutrients in the dilution water may be used up and the effect produced may be

due to malnutrition rather than to toxicity.

The tests described are acute toxicity tests. It is hoped that chronic toxicity tests may be developed in the near future. This would help to determine whether a substance would lower the resistance of an organism so that it could not successfully compete in nature.

Value of Laboratory Toxicity Tests

The tests described would be of value to industry in solving the following types of problems:

1. In the planning of waste disposal, (a) to determine just how much of each type of waste can be safely discharged into a river and (b) to separate the unharmful from the toxic wastes and thus reduce the cost of waste treatment.
2. In changing a process, to determine whether a new process will produce a more severe waste problem.
3. In installing new types of waste treatment, to determine whether the effluent from such a treatment is as harmless as the specifications state.
4. When dumping settling basins at high river flow, to determine how much can be dumped at a given flow without damaging the aquatic life.
5. When an industry is accused of causing a given damage and there are many other effluents emptying into the river, to determine whether or not the accused industry is to blame.

River Surveys

The second approach to solving waste effluent problems is the biological survey of the river. As every aquatic biologist knows, the ecology of the river is a very complex result of many interacting factors. Because of this, no series of toxicity tests can accurately determine the effect of a waste in a river. They merely provide an approximation of what will happen. The only way to know the effect of a waste on a river is to study the river itself.

The methodology for conducting a biological survey was published in the *Proceedings of the Academy of Natural Sciences of Philadelphia* in 1949. In a river survey, all of the organisms established in a given region of the river are identified as to species. The chemical characteristics of the water are determined. A total bacterial count and a coliform count are made, and the B.O.D.'s are determined.

A histogram is made of each region studied. The heights of the columns are determined by the number of species of each group of organisms living in that part of the river. Since the various groups vary greatly as to the number of species in them, the height of a given column is expressed as a percentage of the number of species of that group found in a river not adversely affected by pollution. By this method the various columns are comparable.

From the pattern developed by the columns of a histogram, the state of "health" of a river is determined. Research makes it evident that the pattern of life based on all groups of organisms is a more reliable criterion for judging the "health" of a river than a single group of "indicator organisms." Just as in other scientific work, the more different evidence available to support conclusions, the more valid they usually are.

Value of River Surveys

One of the great values of this type of study is that it tells the condition in the river over a period of time. Because these aquatic organisms have life histories of varying lengths, one is able by examining the structure of the population to determine when in the past a deleterious effect occurred. This effect can be picked up over a period of a year and sometimes longer. It depends, of course, on the kind and duration of the pollution.

This type of river study may be of use to the industrialist in the following ways:

1. Such a survey before an industry starts to operate will define the condition of the river at that time. There are few large rivers in the eastern part of the United States which have not to some degree been adversely affected by pollution. It is well for the state authorities, as well as the industry, to know what the condition of the river is before the industry starts to operate.

2. This method is useful in determining whether a waste treatment program is sufficient to protect the river, or if more treatment is needed.

3. If an industry is accused of damaging a river, such a survey, comparing various sections of a river, can tell if the complaint is justified.

Such a survey is certainly the most direct approach to use in determining the condition of the river. It is believed that by the previously described toxicity tests and biological surveys definite methods have been developed which should be of great aid to industries and to states in defining their pollution problems.

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DISCUSSION

By Arden R. Gaufin and Clarence M. Tarzwell

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Cleaning up the rivers, lakes, and bays of the country will require a great deal of money and the cooperative effort of many different groups of people. To accomplish this task and properly control the disposal of industrial and municipal wastes into surface waters, the pollutional nature of these wastes and their influence on aquatic life must be considered.

The value of fishery resources and the magnitude of the economic loss caused by the destruction of aquatic life by the industrial and municipal pollution of waters are being more widely recognized. Many states have adopted legal measures providing for the protection of fish and other aquatic life from pollution. While some have interpreted this legislation as applying only to the acute poisoning or killing of fish, Dr. Patrick's group has dealt with the fish food organisms, as well as the fish, and also has given consideration to the chronic effects of wastes on aquatic life.

In studying the effect of pollution on a river, the best type of biological program is that which recognizes the complexity of the ecological factors involved. In combining laboratory tests with river surveys, the author is attempting to gather as many different types of evidence as possible before drawing any conclusions. She is to be commended for using an approach which is more thorough than that normally used in the past for examination of this complex problem.

The need for experimental studies dealing with the toxicity of pollutants to aquatic life is great. Dr. Patrick has already discussed some of the methods and the importance of conducting such toxicity tests. Fish bio-assay procedures for most industrial wastes are not costly and are not especially difficult to perform. On the basis of toxicity determinations, it is usually possible to predict whether a waste can be discharged at a given rate without causing direct injury to fish in the receiving water. Such data also are helpful in determining the amount of treat-

ment required, the portion of the waste requiring treatment, and the effectiveness of treatment methods (1).

It has been mentioned by Dr. Patrick that another use of this method is to determine whether the discharges of a given industry are responsible for causing damage when there are many effluents emptying into the river. In such a case the character of the receiving stream is of considerable importance in determining the toxicity of a waste. Further, the toxicity of wastes can be greatly influenced by interactions between their individual components and the dissolved minerals present in widely varying amounts in receiving waters. For instance, the salts of heavy metals are generally more toxic in soft or acid waters than they are in alkaline water. Synergy and antagonism must be considered. For example, mixed solutions of cupric and zinc salts have been found to be much more toxic to minnows, than either metallic salt alone (2).

Dr. Patrick's method for conducting a biological survey of a river is to be commended for the completeness of its scope and for attempting to formulate criteria which might be useful in evaluating the effects of pollution on streams. However, for many purposes it should not be necessary to conduct such extensive or complicated studies as those outlined.

The concept of a healthy stream as being one with a large number and wide variety of species may serve as an index of conditions in some streams, but there are many areas in which it will not apply. For example, in many of the purest streams the variety and abundance of both fish and invertebrate life is distinctly limited. In Colorado and Utah many trout streams have a fish fauna of as few as 3 to 5 species and the variety and abundance of bottom fauna depends largely on the geological nature of the drainage basin (3)(4). The water in these streams is clear, sparkling, and usually meets drinking-water standards. These streams are not biologically abnormal or polluted from any standpoint.

Although heavy pollution drastically reduces the number and variety of species in a stream, limited organic pollution may fertilize a stream and increase production. There is also a great increase in the varieties of aquatic life following recovery in streams polluted with many organic wastes. Many polluted streams have a greater number of fish species than do the purest streams. Indices of stream conditions developed in a local area should be applied only in those areas having similar ecological characteristics.

In stream sanitation work it is not essential that the biodynamic cycle be preserved in its primitive condition. Such conditions have already been largely eliminated by deforestation, overgrazing, mining, and agricultural practices. The objective now is to manage waters so that they will produce the maximum sustained yield of recreation and sport and commercial fishing consistent with the capacity and other reasonable uses of the waters. Among the aquatic fresh-water organisms, fish are the most important to the general public. The destruction of a few sensitive species is of little importance if they are replaced by others equally desirable so that the fish yield is not impaired. In the final analysis the fish yield is the important measure of effective stream management and fish-life should be considered as the major index of stream conditions.

Dr. Patrick's system for making stream surveys is costly and requires the help of a considerable number of well-trained scientists for it to be usable. Many state agencies charged with water pollution control, as well as small industries, do not have money or personnel for a biological program of the magnitude recommended.

When conducting biological investigations for the evaluation or solution of pollution problems, careful formulation of objectives is required. If the

objective is to determine only general stream conditions, a reconnaissance survey is favored to determine the relative quantitative and qualitative aspects of the biota. In such a program the pollutional condition of a stream can often be determined by reference to those groups of organisms which best reflect the ecological conditions under which they live. If the objective of a stream survey is to ascertain the economic loss caused by the damaging effects of pollutants on the fishery of the stream, then it is necessary to determine the composition of the fish fauna in the stream and the changes in that fauna which might have occurred in the past. Necessary data on fish populations and yield can be obtained by creel censuses, records of commercial catches, seining, gill netting, trapping, etc. Since the procedures for conducting fishery yield surveys have been fairly well standardized by workers in fish management, it is not deemed advisable to dwell further on the subject here.

Several different approaches have been advocated by biologists in using aquatic organisms as indicators of the pollutional conditions of a stream. Dr. Patrick, emphasizing primarily a qualitative approach, maintains that the total number of species, rather than the qualitative and quantitative characteristics of the population, constitutes the most valuable index as to the health of a stream. Ellis (5) advocated a semi-quantitative approach when he stated that the relative abundance of indicator species was the important consideration. Biologists of the USPHS Environmental Health Center at Cincinnati, Ohio, have found that both criteria are important and serve best when used concurrently. For example, Gaufin and Tarzwell (6) found that in a small polluted stream near Cincinnati, the biota in the polluted zones was characterized by few species but large numbers of individuals, whereas in the clean-water zones there were many species but comparatively few individuals of each species.

Quantitative measurements of the total number of species or individual organisms in any given area of a stream are often difficult to obtain. For example, Environmental Health Center biologists took a series of nine random samples, by means of an Ekman dredge, from a pool in a small sewage polluted stream near Cincinnati. A total of 50 species of macro-invertebrates was collected. On the average, it was determined that any three of these samples would have yielded only 60 per cent of the 50 species. Seven samples would have been required to have obtained 90 per cent of the types represented.

Where personnel are not available to do all of the technical taxonomic work required for species identification, or to take enough quantitative samples to accurately determine the abundance of individual species or organisms, a practical biological inventory is still possible.

Specifically, the degree and extent of pollution in a stream can be determined accurately by reference to the macro-invertebrate fauna, particularly that found in the riffles. A biological analysis of the pollutional status of a stream can be obtained in the field through recognition of the biological orders, families, or genera in the invertebrate associations encountered. This type of biological inventory is superior to limited chemical data, as the complex of such organisms which develops in a given area is in turn indicative of present, as well as past, environmental conditions in that area. Bottom organisms are more fixed in their habitat than are fish or plankton and cannot move to more favorable surroundings when pollutional conditions are most critical.

Shortened procedures, such as that suggested, cannot be recommended for use by anyone except a well-trained aquatic biologist. When used properly, however, such techniques can be of considerable value to organizations having waste disposal problems to solve.

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DISCUSSION

By Ruth Patrick

As Dr. Gaufin has pointed out, there may be a synergistic effect between an effluent entering a river and substances already in a river. For this reason toxicity tests may be used as a yardstick, but one must study the river itself to determine accurately the effect of an effluent.

It is true that there are many different types of rivers in the country, with varying amounts of aquatic life. However, the writer has yet to find a river with two ecologically similar areas; one adversely affected by pollution with industrial or municipal wastes, and one unpolluted in which the unpolluted area did not have a greater diversity of species of diatoms, insects, and fish than the polluted area.

It is correct that a well-qualified biologist can determine that a river is badly polluted without determining all the species. But if it is desired to determine trends of conditions or have definite evidence for future comparison, the species present must be determined.

Very rarely are all the species of a genus indicators of pollution. For this reason, it would be very dangerous to draw positive conclusions from determination only to genus.

Dr. Gaufin indicated that the method described is a qualitative one. It is qualitative in that the kinds of species composing the biodynamic cycle are considered. It is, however, quantitative in that the measure also considers the number of species. No one has yet devised a statistically valid quantitative method for benthic forms in a river based upon the number of individuals.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

JOB APPRAISALS AND OPERATOR CERTIFICATION

That the subject of job classification already has received considerable attention from a few of the larger municipal sewage treatment organizations is borne out by the extensive and interesting discussion of the matter during the "Operators' Forum" at the Federations' New York meeting, as reported on pages 225 to 230 of this issue. The discussion points out some of the pitfalls to be avoided in applying job classification to the types of employment found in sewage works. In general, however, it has a tone of enthusiastic response to the job classification program.

Nevertheless, it is somewhat disappointing to note that none of the discussers mentioned one advantage of job classification that is felt to merit such special attention that we did not include it in a previous discussion (THIS JOURNAL, **25**, 1, 87; Jan., 1953), but held it over for a little "extra" treatment by itself.

We refer to the peculiar advantage that job classification has for sewage works personnel in the direction of operator certification. In some states —Illinois is a notable example—one of the requirements of a certification application is a "service rating" based on a statement by the applicant of the duties and responsibilities of each job he has held. Here is use by one type of regulatory body of the principles of job classification as a basis for assessing the applicant's competence to perform satisfactorily at the level for which certification is sought. Much time and effort often must be expended to check the applicant's statements against the true facts.

How much easier the whole matter becomes for both the applicant and the certification board when a definite, clear, concise statement of the applicant's entire duties and responsibilities can be given—especially if drawn up by a disinterested third party!

The full program of job classification, including job evaluation, job rating, and job pricing, probably has not been attempted to any great extent in most sewage works staffs. Many small plant staffs trying to inaugurate such a program face opposition from those who believe that any such attempt is automatically reserved for the "big" plant, on the basis that time and money are not justifiably expendable for what they consider "frills." But at least the early stages have been carried out, whether consciously or not, in filling almost every job, or justifying every raise in pay, in almost every plant from the smallest to the largest. Moreover, in those cases where the program has been carried out fully, results seem generally to have been most satisfactory to all concerned.

As more and more plant staffs come under fully implemented job classification programs, there cannot help but be a growing realization by those who hold the local purse strings that the job of the operator entails many skills and much responsibility. This alone could well be a key objective in the continuing crusade to better the lot of plant operating personnel!

H. P. O.

1952 OPERATORS' FORUM *

J. HENRY L. GILES, *Leader*
Assistant City Engineer, Meriden, Conn.

Chairman Giles:—The Forum program lists several topics, not necessarily in the order of their importance or interest, but simply as a convenient framework within which to encourage discussion from the floor by and for the benefit of the operators.

Pumps

Clarence E. Keefer, Deputy Sewerage Engineer, Bureau of Sewers, Baltimore, Md.:—There are just two points that I would like to say a word about. Occasionally, I have had the opportunity of reviewing the design of small sewage pumping stations, and on one or two occasions it was found that the engineer has used submerged pumps. There is nothing worse than submerging a pump and asking somebody to operate under those conditions.

The second item many people overlook, but which nevertheless can present a great headache, is to be sure that the pressure of lubricating water on the sleeve where it passes through the packing gland of a pump is sufficient to prevent any sewage or matter in the sewage from passing out through the pump liner.

Some years ago we had a pump on which the sleeves were wearing out in a matter of hours. Various kinds of metal were tried, but within 2 to 4 hr. the sleeve would be ground down and another would have to be put on. After making an investigation, the first point of approach was to put a pressure gage on the water pipe adjacent to the sleeve. The water pressure at that point proved to be only a matter of a few pounds, and the pump was delivering a pressure of perhaps 30 or 40 lb.

The result was, of course, that material was being forced out through the sleeve. The packing at that point was collecting foreign material, which was abrading the shaft and sleeve. Since then, we have always been sure to have ample water pressure at that point.

As regards water supply to the sleeves of pumps, it is pretty generally established that cross-connections at that point are undesirable. Therefore, it is general practice to use some device, probably a storage tank or a supplementary pump, to build up pressure without the hazard of a cross-connection at that particular point.

In selecting sewage pumps or sludge pumps, it is desirable to avoid characteristic curves that are quite flat. If it has been decided to design on the basis of a certain head and a slight error has been made, the selected pump may give insufficient capacity with a flat characteristic curve. It is always desirable, therefore, to have a rather steep characteristic curve for the pumps selected.

Question from the floor:—Is it proper to use grease packing on those pumps?

Mr. Keefer:—I would say so. The Baltimore Bureau of Sewers has a matter of 30 or 40 pumps for various purposes—pumping sewage, pumping sludge, pumping chemicals, etc. The standard practice there is not to use grease, except in very unusual conditions. I prefer the use of water.

Thomas A. Berrigan, Director and Chief Engineer, Sewer Div., Metropolitan Dist. Comm., Boston, Mass.:—We are concerned with grit in pumping sewage. Most people feel that in a pumping operation the grit chamber

* From transcript, 25th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; New York, N. Y.; Oct. 6–9, 1952. [The remainder of the Forum discussion will appear in an early issue.—Ed.]

should be ahead of the pump so as to eliminate all the grit possible.

Unnecessary handling of grit is costly. For 50 years, Boston has been pumping grit and raw sewage into the harbor. It is my feeling that the grit should still be pumped into the harbor after it has been washed. Of course, it would be a big mistake to let it get into sludge digestion tanks, but it seems very proper that we should push it into the sea. This type of grit disposal has been followed for more than 50 years without impeding navigation. There is no reason why we should become involved in a special grit washing job, a special trucking job, and a disposal area, which would be objected to in concentrated areas. It is my general feeling, then, that even though grit may wear out pumps and involve packing problems, nevertheless they should be used to move that same grit.

As regards force mains, there is one other experience that may be of interest. At our Ward Street pumping station, some research work was being done on sedimentation and we had a marvelous sedimentation tank that we were experimenting with. To get effluent into the tank, a garbage disposal unit was used to simulate a comminutor, and in making the test, a small discharge line was taken from the force main.

However, the capacity was not up to the amount desired and the research engineers were quite concerned about putting in an extra pump to give greater capacity. The power plant engineer said, "Well, Mr. Berrigan, if you can stand a little extra force for 5 or 10 min., I can give it to you."

What he did was to shut down the discharge main, increase the head, and, of course, increase the sewage discharge to the model. It was a very clever trick, and something that the rest of us could learn something from.

Chairman Giles:—If you are going to continue to pump grit into Boston Harbor all these years, what is the capacity of the harbor?

Mr. Berrigan:—At low tide, the capacity in the basin is about 400 times the regular flow. The tidal prism that comes in there per day is about 350 times the total flow. The practice has been followed for more than 50 years and nothing has happened. The ship channels seem to be perfect. There has not been a complaint on navigation in all that time.

Mr. Keefer:—I would like to make another query here that ties in with sewage pumping stations, and that relates to valves. Has anyone had any experience with the plug-type valve *versus* the gate valve?

Edwin A. Locke, Operator, Sewage Treatment Plant, Hartford, Conn.:—We have quite a number of plug valves in use. On the sewage pumps, however, we use gate valves.

The plug valve is very good when it is used frequently, but if it isn't used, lubricated, and turned to 90°, there is liable to be trouble due to sticking. Then you have the job of getting it started. We have found it necessary to be extremely cautious when using the plug valves on sludge lines, particularly around the digesters, as gas under the plug will make it very difficult to turn.

Plant Laboratories

Chairman Giles:—Sewage plant laboratories is the next subject, including the size, equipment, tests, use, and application of laboratories. That is an endless subject, considering the range from a plant that has nothing but a couple of pH testing outfits to an establishment in such cities as Chicago or New York, where they have a full staff of chemists, bacteriologists, and other specialists.

What is the extent of the variations in laboratories, as regards size and equipment? What might laboratories be used for, other than just the more apparent and obvious testing of sew-

age, to help in operation, maintenance, and extension of a system?

E. Sherman Chase, Consulting Engineer, Boston, Mass.:—For many years I have said that the best apparatus a sewage plant operator could have consists of his eyes, his nose, and a brain to apply what the eyes and nose see and smell. Those three fundamentals are the basis upon which all laboratory work should be built. You may have all the laboratory scientific equipment, you may have the finest layout for your laboratory, and you may collect tons and tons of data; if you have not an operator who uses his eyes and his nose and his intelligence, you might just as well have saved your money in the first place and not built that laboratory or purchased that scientific equipment.

Unless the data collected in the plant laboratory are utilized for the benefit of your own plant and for the benefit of other operators and the designing engineer, the laboratory might just as well not be in existence.

Chairman Giles:—I think the point Mr. Chase is making is that a good operator is better than a good laboratory. On the other hand, sometimes a good laboratory is a big help to a good operator.

LeRoy W. Van Kleeck, Prin. Sanitary Engineer, State Department of Health, Hartford, Conn.:—The average small plant operator in Connecticut generally uses the Imhoff settling, pH, and chlorine residual tests. I have tried to interest the operators in substituting the total alkalinity test for the pH test in control of digesters. Also, I think the settling test is helpful for determining the quality of supernatant liquor; that is, settling it in a cylinder for 30 min. If there is less than 10 per cent, the quality of the liquor is good. In other words, it will meet the standards for suspended solids, which should be under 2,000 p.p.m.

When it comes to secondary treatment plants, the small plant operator in Connecitcut is generally running a stability test, at least. We are not going, in most cases, to B.O.D. tests.

John O. Barrett, Superintendent, Westerly Sewage Treatment Plant, Cleveland, Ohio:—The eyes and nose may help the operator to operate a plant, but I believe a laboratory is needed for bacteriological work to satisfy the newspapers.

Edwin B. Cobb, Consulting Engineer, Boston, Mass.:—The size of laboratories is a question that has bothered us somewhat in laying out plants. I have been to a number of plants, especially through New England, and have been rather disappointed to see the large laboratories people have designed and then no use is made of them. One reason, apparently, has been that the people who laid out the laboratory forgot that the plant was not going to hire a chemist. When they ended up with an operator who was not chemically trained, a lot of the equipment lay idle.

To avoid that mistake in the future, an attempt should be made to look into what is needed. After several conferences with a man who is, perhaps, one of the best sewage chemists in the field, we came down to a laboratory in one plant that cost $1,000. The room is about 10 ft. by 16 ft. in size, which is adequate to hold the equipment.

It was found that one of the principal uses of the laboratories in that area was by the state engineers in making their routine tests. With that in mind, in one particular case, we called on a state engineer to give us a list of the equipment he would like to have. On that basis—using the advice of our own chemist and what the state engineer would like—we came up with a room to do the job that cost about $1,000, exclusive of the sink and bench and a few things like that.

Chairman Giles:—I have in mind one laboratory that is the lunch room and place for relaxation during the noon hour.

As Mr. Cobb has pointed out, it does seem a shame to put in several thousand dollars worth of equipment and facilities if either in the present or in the immediate future it is not planned to be used. Those facilities could be added later when they are needed. However, it encourages an operator to do some laboratory work if he has some facilities. It behooves the consulting engineer to provide some of those facilities as he talks with the local administration on what their set-up will be and with the state representatives on what tests they might like to have made at the plant.

Frank H. Miller, Chief Engineer, Hampton Roads Sanitation Dist. Comm., Norfolk, Va.:—I would like to say a word in favor of rather adequate laboratory facilities. In Hampton Roads we have central control of the three plants and believe in rather complete laboratory work. The laboratory has been invaluable in three main problems that the District has faced. One problem is that we allow wastes that do not need to go into the sanitary sewer to be discharged into the storm sewer system. The laboratory is used to find out what wastes can be so diverted from the sanitary system.

The second use is to trace industrial wastes that would do damage to the system. In several instances, wastes have been traced which probably would have been found only over a much longer period without the good laboratory control.

The third thing is the high salt problem. We have about 100 pumping stations, extensive force mains, and also some siphoning systems. Through the laboratory close control is maintained on chloride infiltration.

John R. Szymanski, Superintendent, Sewage Treatment Plant, New Britain, Conn.:—We happen to have quite an intricate problem, as we are using the Guggenheim biochemical process in treating the waste. In the first place, the laboratory has been an invaluable aid in controlling the system.

In the second place, our receiving stream is the plant effluent. For the past five years, during the months of June, July, August, and September, the neighbors below have complained. If it were not for the laboratory control and laboratory analyses of the stream below the plant, those complaints would be unanswerable. Notwithstanding the fact that the laboratory is used practically entirely for plant control, we do analyze samples taken below the plant for a distance of about 8 mi. With the laboratory results obtained on this stream we are able to face our neighbors below the plant and say, "Look. Our plant is doing this, and until proven otherwise we will try to maintain our present level of treatment, or try to make it better."

Without the laboratory, however, we would have no defense. A laboratory is a great deal of aid in any installation, whether large or small, as it gives complete control of all the needed data and of the plant processes.

The routine tests run at the New Britain plant consist of suspended solids, B.O.D., ammonia, and iron determinations. We originally were called the "ironbound" plant. Iron waste or pickle waste coming from the local industrial plants runs anywhere from 100 to 800 p.p.m. of iron in either the ferrous or ferric state. It is quite essential to keep a fairly close check on these iron wastes.

However, besides the iron determination, we also run the usual stability tests. I have done some of the other non-pertinent tests, which make good reading but do not mean too much in the over-all picture. It is nice to have the data, but in the long run it will be found that the basic tests are those for B.O.D. and alkalinities.

There are many tests that can be run that probably do not mean too much as far as plant control is concerned. However, over a period of years it may

be possible to correlate these facts and figures and get something unexpected out of them.

L. H. Enslow, Editor, Water and Sewage Works Magazine, New York, N. Y.:—Many of us laboriously make pH tests on the liquor in the digester and it is troublesome and often costly. To my mind, the best test that can be made is a routine CO_2 test on the digester gas. Such a test is worth many, many times the value of the pH test. It is easy to do, it is accurate, and the entire contents of the digester are sampled at once when you take a gas sample. Also, it is a uniform sample. There is no guesswork about it, and you are about two weeks ahead of the pH test as to the trend the digester action is taking. There is no need to get excited on the first test, but if the CO_2 content remains high in a series of three tests you had better be doing something about it.

Question from the floor:—How is the CO_2 test interpreted?

Mr. Enslow:—It is strictly an indication of acidity. As the alkalinity goes down, the acidity goes up, and there will be more CO_2 in the gas. A definite value cannot be set, because every digester has a slightly different formula for the gas. After you know what the specific formula is for normal digestion in your particular digester, just as soon as the CO_2 curve begins to rise and the trend is continuous, there is time to do something about it before it gets too bad. With the pH test, however, it can't be caught that far ahead.

Question from the floor:—Is the sodium hydroxide absorption test a good method of getting the CO_2 content of the gas? Gas analysis apparatus is quite expensive.

Mr. Enslow:—It is a simple test to run. The question really is: Do you need an Orsat outfit to make this test? The answer is no. It can be made with a caustic soda solution. What is lost through absorption by bubbling it through a caustic soda solution will give an ample, accurate result and a lot of gas can be put through a strong solution. There is no need for using a small sample in this test. In fact, gas can be bubbled through the solution a whole half-day, while other work is being done. The test can then be made with great accuracy.

Mr. Chase:—A fundamental factor in good laboratory work is good samples. Years ago, as an operator, I suspected that the man on night duty, who was supposed to be collecting samples throughout the night, was failing to do so. The suspicion was based on the results of the nitrate determination in the final effluent of the filter plant.

I knew from 24-hr. individual samples what to expect in the composite sample for the nitrate content of the final effluent. The results began to indicate that something was amiss. I suspected what was taking place; that the night man was collecting all his samples at one time when he went on duty.

The analytical element was combined with some physical evidence following a light fall of snow in the early evening. The first thing the following morning, it was noted that there was only one set of footprints to the sampling point. When the analytical and meteorological evidence was presented to the City Engineer the operator lost his job.

Ralph A. Hoot, Superintendent, Sewage Disposal Plants, Philadelphia, Pa.:—Philadelphia is in the process of equipping laboratories at three separate plants. Rehabilitation of the laboratory at the Northeast works has been completed. The administration building was built 25 years ago, when the Imhoff tank system was put in, and we recently rehabilitated the laboratory at a cost of about $7,000.

I have been a little surprised to hear one or two discussers even mention the cost of gas analysis equipment. Certainly the equipment is a very desirable thing, and I, for one, intend to

spend any amount of money to get the right kind of equipment in the laboratory.

At Philadelphia, I requested 24-hr. control, which meant a chemist on every shift. To a pretty good degree, we have that at Philadelphia now. Although I asked for three young men who had had some chemical training in college, we couldn't find them in Philadelphia because of the scarcity of of chemists in that area. Therefore, we hired three non-technically trained men who had quite a bit of intelligence, and started to make chemists out of them. That was a year ago. During the first three months, the results were disconcerting to one like myself, in charge of a plant, but it is amazing what those three men have done.

Another innovation at Philadelphia, and one I am proud of, is having men who do nothing but sampling. When I was at the Fort Wayne, Ind., plant, the operators collected their own samples and brought them into the laboratory. In Fort Wayne there was one central building, more or less. A man did not have to walk too far to get sewage samples and sludge samples. But in Philadelphia, the distances are great, so we have samplers working around the clock. These men have a jeep, in which they travel about the plant to collect their samples. They collect not only sewage samples, but sludge samples as well. Of course, they have to cooperate with the sludge operator for the latter.

Mr. Chase mentioned being certain that you get your samples. At Philadelphia we make sure the samplers get their proper samples. This is an outgrowth of some trouble along this line at Fort Wayne. There our electrician rigged the refrigerator door to record every time it was opened. Although we couldn't prove that the man opened the door and put a sample in, at least we could prove that the door was opened. The gadget was so sensitive that we determined that the night man also kept a candy bar in there: it took 6 sec. to get a candy bar, but if he reached in to leave a sample it took 15 sec. Unknown to the operators, this gadget was installed, and later on the evidence was brought up that one of the operators had gone only once that night to get a candy bar and had not deposited a single sample.

Strange as it may seem, the A.F.L. union made the accusation that we were being unfair to organized labor.

At Philadelphia, two other plants are to be constructed. They will be primary treatment plants, whereas the Northeast plant is of the modified aeration type. Although there will be around-the-clock sampling, but not special sampling, only daytime control will be used at those two plants and both laboratories will be less elaborate than the one at the Northeast plant.

One of these laboratories has already been sketched out and the other is being drawn out in our minds. A number of different concerns were asked to provide rough sketches, from which to start as a planning basis.

Once again, I don't believe in sparing money, and I don't believe in wasting money. Money should be spent judiciously. Whatever equipment is needed for those plants is certainly going to be purchased.

A. H. Niles, Superintendent, Sewage Treatment Works, Toledo, Ohio:—We had the same situation, in which we got samples at night that were all practically identical. We knew they were taken all at the same time, but it was very difficult to prove. We did not have to have the meteorological advantages that Mr. Chase has told about. It was decided that, after warning the operators, a time clock with a key station would be installed. We take samples on the hour, every hour, and bring them to the laboratory. At least now the samplers have to punch the time clock when they get the samples.

We had one fellow who used to call that the "stool-pigeon." Well, he ran

afoul of the stool-pigeon and resigned rather than face charges before the Civil Service Commission.

Chairman Giles:—These last remarks certainly illustrate the difference betwen a city of 1,000,000 or more population and the cities that many of us have experience with of 20,000 to 50,000 popualtion, where the superintendent is his own chemist; or the even greater contrast with cities where the superintendent is not even allowed a pick-up truck in order to do his necessary work, and has to use his own car for getting equipment. This is mentioned to bring out the fact that there are limitations imposed by conditions in the city, regardless of how good we are in selling the needs of laboratories, laboratory equipment, and laboratory personnel.

Personnel

Chairman Giles:—The subject of personnel is an intriguing one. It includes the operators, laboratory men, sewer maintenance crews, and so-called laborers.

I have been concerned many times about the rating that many sewage works operators have, especially in some of the small and medium-sized cities, where, if there is a second man at all, he is a laborer.

In reviewing the activities of those men, it certainly involves experience and initiative, as well as just plain common sense. I had hoped that many superintendents, city engineers, and sewer authority groups would give the men operating the sewage plants a higher rating than laborers. It may be that their pay cannot be increased immediately commensurate with title, but at least they could be given the rating of "Sewage Works Operator." Then to try later to give them a pay scale commensurate with that rating, if possible, would be desirable.

Mr. Niles:—We start our prospective operators as laborers. That is the recruitment level. It is hard, of course, to get laborers with sufficient educational background to make operators out of them. Educational levels run all the way from, say, sixth grade through high school, possibly even college. You cannot keep these last, however; they have ideas and want to better themselves. Therefore, you are stuck with men having educational backgrounds of about the high school level or lower.

Our pay scale for laborers entering is $1.54 per hour. After three months, they go on a monthly rate, which is slightly more than $1.54, but they then have accumulated sick leave and vacation pay benefits. The operators, of course, have a higher pay scale. We hope in the near future to put through a pay scale in which experience will be considered on a point basis, so that they can get increased annual increments to about seven years. That is designed to help hold the good men, along with Civil Service.

Roy F. Weston, Sanitary Engineer, Atlantic Refining Co., Philadelphia, Pa.:—Industry uses a system for determining pay rates that may be of interest to people in the sewage works field. That is a scheme of things known as "job analysis and evaluation."

One large company uses a system of that type in which they try to rate separately such factors as mental effort, physical effort, responsibility, working conditions, and others. They set up a point system by which they get a relative rating of jobs and then, depending upon the pay scales in the area, they can determine the relative pay rates of the different jobs analyzed.

It is hoped that the Pennsylvania Sewage and Industrial Wastes Association will be able to establish a committee to study the possibilities of the use or the application of this system to the sewage works field within the next year.

Chairman Giles:—The New England

Sewage and Industrial Wastes Association has had an Operator's Salary Committee for years. Such a committee ought to be continued and probably make yearly amendments to their recommendations.

Henry J. Graeser, Assistant Superintendent, Dallas Water Dept., Dallas, Tex.:—Two Texas municipalities represented here have tried job evaluation. It is a very interesting procedure, and has been tried at Austin and at Dallas.

It is a rather formidable task at first attempt, but after seeing what it is and how it works, it is probably the most equitable way to establish a salary schedule. Actually, every supervisor must go to some higher authority in trying to secure more equitable wages for his personnel. Therefore, in one degree or another, he must establish job sheets and job requirements. That is where job evaluation begins.

At Dallas, and I believe also at Austin, a consulting firm was hired to come in and write job sheets and job analyses on all the jobs in the city. Then a Job Evaluation Committee, composed preferably of department heads and their assistants, rated the jobs. This was a difficult task. Key jobs were selected, as previously mentioned, and the number of points assigned to these jobs was broken down on the factors of responsibility, on-job training, and physical hazards. When you get through a man might have the pre-job requirements of a chemist and the on-job requirements of a clerk in the office; he might have the responsibility of a business manager and the physical hazards of a chair-borne administrator. Summation of the points for the various job factors gives the total of job analysis points.

Each supervisor, regardless of how large or how small his plant may be, can perform the first part of the program himself by writing up the various job sheets. That way you have the information on paper and know exactly what each man has to do, what your estimate of the job is on a considered basis, and what type of pre-job experience and on-job experience is required. Then when you approach the Civil Service people and try to get a better rate for your operators, if they are classified—or your Personnel Department, if they are unclassified—you know your position.

Louis B. Harrison, Superintendent of Filtration, Bay City, Mich.:—At Bay City there is a peculiar pay rate arrangement in the Water Department and the Electric Light Department. The same peculiar rate is going to apply to the Sewage Disposal Division, when the plant, now under construction, is completed. All of these departments are considered public utilities. As such they are fully organized, originally under the C.I.O., but at present under a Municipal Employees' Association. They have succeeded in tying the city utilities in with the privately-owned utilities as far as union activities are concerned.

The rate for operators is $2.28 per hour. All employees, with the exception of supervision, come under a rate schedule based on a curve. Now we have an arrangement to put supervision under the same category, because it was figured that within the next five years operators would be making more than superintendents and their assistants.

In the discussion on classifying employees, rates were not mentioned. What do others pay for jobs? On the present arrangement, operators at Bay City will be getting, within a year, probably $2.50 per hour.

Mr. Szymanski:—This is an example of honesty not usually being the best policy. In New Britain, we came under a compensation and classification plan about a year ago. Prior to that, the Personnel Director contacted each department and asked the department

head to outline the duties and the basic minimum requirements for each position.

The men employed at the New Britain sewage plant come under a separate commission—an unbiased commission composed of engineers in the city. The chairman was confronted with the questionnaire, especially the part about basic requirements. He contacted the Personnel Director and said: "Do you actually mean what you say there; basic minimum requirements for the job?" Naturally, the Personnel Director said, "Of course."

Consequently, after the duties were outlined for operator, senior operator, and laborer, we found ourselves in a mess. In the first place, to be honest about basic requirements for a sewage plant laborer or sewage plant operator, we went down to the roots of the thing and said, "Well, all of our men, although they are duly qualified, haven't a college education or they have just about got through high school. They are doing a good job, but let us be honest about it and say that all they need is the ability to read, write, follow written instructions, and to be able to do actual physical work, if necessary."

So, when the program was completed and the sewage plant employees were rated, we found ourselves at the bottom of the totem pole and fighting to get a raise in pay. Other departments embellished their requirements and the case of the men at the sewage plant became a lost cause.

The point being made is in the competitive field of writing "flowery" job descriptions of the plant operator's job. Let's be honest with the men when we do classify them. Let's give them what they have coming to them, and not stick to the absolute basic requirements, whether it be for a "laborer" or an operator.

It has been a big problem. The men become more or less restive and antagonistic. The efficiency of the work done by an operator is liable to suffer if his job isn't built up somewhat, which makes it practically impossible to be completely honest as regards basic minimum job requirements.

Chairman Giles:—Can you give some idea of the pay scale between the lowest and maximum of your operators?

Mr. Szymanski:—Our so-called "laborers" start at $1.50 per hour. They have a 40-hr. work week, two weeks vacation with pay, and 90 days cumulative sick leave. They get one day sick leave per month of work.

The assistant operators, due to improper classification, are in the same pay class as laborers. This is because of the previously mentioned statement on basic minimum requirements.

A senior operator, or the operator in charge of a shift, receives $74 per week, with two weeks vacation, and 90 days sick leave cumulative at 1 day per month.

The clerk-secretary falls into a peculiar status. For years the plant had a trained chemist. With the advent of World War II, it became so difficult to compete against the armed services that I took the secretary from the office and broke her in to laboratory routine. Consequently, the poor girl now has to do laboratory work in the morning and office work in the afternoon. So she is paid $60 per week.

Chairman Giles: At Meriden, Conn., an attempt is being made to work out more equitable pay scales. At present the laborers are receiving $1.31 per hour.

A. H. Ullrich, Superintendent, Sewage Treatment Plant, Austin, Tex.:—At Austin, the job classification plan has been in operation for about a year. In our case, the City Manager instituted the job evaluation program and hired a consultant to teach us how to do it, although we carried out the program ourselves. Not only did we, as a committee, evaluate the job, but we used our own personnel to write the job specifications.

We have about 16 job analysts who were trained by the consultant—or, at least, he helped train the job analysts from the various departments. These analysts went out and called on each person working for the city. Of course, where three or four laborers were doing the same type of work, possibly only one laborer was interviewed; but all of the laborers had to sign their respective job specification sheets. In other words, the job analyst interviewed the individual and found out what his job actually entailed. The individual would then sign the sheet as proof that that is what he actually did. The job specifications would then go to the department head for checking and signature as further proof of the employee's actual tasks.

A committee of seven was appointed by the City Manager after nominations had been made by the department heads and other administrators. These included the Finance Director, the City Attorney, the Director of Public Works, the Assistant Director of Electric Distribution, the Assistant Director of the Hospital Laboratory, the Fire Marshal, and myself. Obviously, the group represented the different municipal departments.

Other department heads were at first rather annoyed because they were not selected for the committee. After the committee was in operation about a month, however, they were very happy that they hadn't been appointed. You can imagine what a tremendous job such a committee would have in a city that has practically every type of service imaginable—from cemeteries to police department, fire department, all the various phases of recreation, a municipal hospital, and all the utilities except gas and telephone.

The committee was told that there would only be about 250 job classifications; in other words, that a lot of the jobs would be the same and that there would be only one specification to read and analyze. Eventually there were some 650 different specifications out of a total employment of about 1,700 people.

It was fairly easy, after arriving at a key scale, to pretty well evaluate jobs in the lower brackets. Where the major differences arose in the committee was in some of the higher brackets in the technical group. A good example of the difficulty is an attempt to compare a Superintendent of Power Plant, for instance, with a Design Engineer. The former is an engineering graduate, is supposed to have a professional engineer's license, supervises a lot of people, and has quite expensive equipment under his control. The Design Engineer, on the other hand, also has much responsibility, but supervises practically no one and has no very expensive equipment under his supervision or control. To try to fit the various factors together and come up with a reasonable answer is quite a problem.

It is impossible to read a job specification in a short while and actually get in your mind what that person does, then compare it with some other job which has already been evaluated, even if originally on the key scale or later in the process of comparing jobs, when there are perhaps three or four sheets of job specifications setting out what that person does. To set aside 30 min. for reading and evaluating each job, when there are 650 jobs involved, means quite a few hours. The only time we had to do that was at night, because the committee met three times a week from 10 AM until a specified number of jobs was completed. As a committee, it usually took from about 10 AM until about 6 PM to rate six jobs, which we had rated previously as individuals. As a committee of seven it was necessary to agree within a certain number of points before the particular job under consideration could be left. All this was, in Army parlance, "in addition to other duties."

A previous discusser mentioned that

honest specifications were written up and came out very low. We had some of that. As a committee, we had to know whether a job was "blown up" or whether a specification was not high enough. Many specifications were raised in committee. It was considered part of the committee's duty. We also "knocked down" many a job, and thereby almost lost some friends.

James A. Liontas, Wastes Control Engineer, Sharpe & Dohme, Philadelphia, Pa.:—Most of the discussion seems to be centered around municipalities, and rightly so, because most of those present are concerned with municipal works. I wonder if anyone has pay scales on industrial plants.

At Sharpe & Dohme, wastes treatment operators start at $1.88 per hour. Their help starts at about $1.50 per hour. I would be interested to know what some other industries pay their operators.

Chairman Giles:—The State of Connecticut recently used job classification to place some 1,200 classifications into 18 pay scale groups, with a 5-year increment for each group. There were many complaints after the classifications were set up; many of the jobs were re-classified, in most cases upward.

The outline presented by Mr. Ullrich was extremely good. A major problem seems to be the middle grade employee, who has rather high technical training, but apparently is working under someone or has no one immediately under him, but has considerable experience. That seems to be the individual whose case has been handled as poorly as any under job classification.

Recruitment has not been mentioned in these discussions. Of course, a lot of that problem has to do with the pay scale. Where an industry is competing for the laborer class of men, or the operator—in other words, those who have to do the work—an adequate pay scale, of course, is very helpful in getting men to do that sort of work. Even though they don't like to do it, if the wage is high enough they will do it, even if they have to be checked on.

Mr. Enslow:—I would like to ask Mr. Ullrich what was done at Austin about the matter of overtime.

Mr. Ullrich:—Incidental to the job classification program, a completely new employee policy was set up. That has not yet been passed by the City Council.

We do pay for overtime. The policy has been to pay monthly employees straight time for overtime. This creates the unfortunate situation that some of the hourly men, if used on overtime, make more money than the foreman, who is on a monthly basis.

Under the new policy all personnel not in first-line supervision will receive time and one-half for overtime pay. Only department heads or those high enough to be able to make themselves overtime will not be so paid.

Mr. Niles:—Perhaps a few words should be added on the pitfalls of job evaluation. We feel qualified to point out a few of them, because this type of program was initiated at Toledo more than five years ago.

It starts out very well. We paid $39,000 for the job, in which the evaluators or the consultants were supposed to do the evaluating. It wound up, however, by city personnel doing most of the work and the consultant collecting the fee. After the rating job was set up and all of the initial complaints of inequalities had been straightened out, a Job Re-Evaluation Board was set up. I happened to be one of the unfortunates appointed to that Board for a while.

That was a real focal point for trouble. Each man thought that his particular job did not get enough points. To prove the necessity of having a job re-evaluated, however, the appeal had to show an oversight in the original job specifications, or that the work had changed and additional

duties were entailed since the job was evaluated.

The result, of course, was that everyone tried to enlarge on his job as much as possible. That was the Board's worst headache outside of the pressure brought to bear by certain groups —the skilled trades, for instance.

As an example of group pressure, in an election year every trade in the skilled trades group high-pressured the Council into overriding the Job Evaluation Board and granting certain increases to this group. Such a move can really upset the whole program.

The same firm of consultants is now being paid $12,000 more to come in and try to straighten out the mess that has accumulated over the 5-year period. The recommendation for annual service increments up to seven years stems from that work. The yearly increments, incidentally, would be based on the original point values for the various jobs. Our points for laborers are about 150 or 153. Points for the highest positions run up to something like 350 or 400.

Mr. Ullrich:—Mr. Niles has certainly brought up a good point: that once the job evaluation program gets out of line you have a hard time trying to get it back.

Unfortunately, I am still on the committee I mentioned previously, which is now re-evaluating jobs. It does not take quite the time that it did, but obviously, with as many jobs involved as at Austin, it was impossible to complete the program by the established deadline of January 1, 1951. The first round was completed, however, by July 1, 1951, with readjusted pay schedules made retroactive to January 1.

Of course, mistakes were made. Therefore, the committee is now in the process of re-evaluating jobs very slowly. This has a tendency to act as a check on getting the thing out of line.

New jobs do change, as Mr. Niles has pointed out. Also, if an employee is dissatisfied with the group that he has been placed in, he can ask for a re-evaluation. Department heads can ask for a re-evaluation of jobs without any job content change. I, myself, have asked for re-classification for some of my employees, because I didn't think the committee, of which I was a member, was quite honest with some of the jobs; we were a little too honest to begin with in trying to write up the time requirements and experience requirements for the job.

Mr. Weston:—Five years ago I had to be convinced that job evaluation classification was a practical thing. I now have 25 jobs in my group and am convinced that it is a remarkable thing. That is because I have finally gotten to the point where I get the same result from job evaluation that a job analyst can.

The very fact that these discussers have found job analysis so complicated, is nothing but an indication that the basic process of determining what a man should get is not a simple proposition. Therefore, job analysis and evaluation acts as an aid to judgment. It acts as a balance wheel for those people who want to overrate their jobs. It acts as a guard against those pressure groups that want to get more pay when it actually is not justified. In that particular sense, job analysis and evaluation is really an excellent thing. It is certainly much better than arbitrary establishment of pay rates by an individual.

I have been able to take salaried employees, when I thought they deserved more pay, and adjust their jobs and make their job duties and responsibilities such that they could get the pay I thought they should get. I have been able to negotiate with the unions and they have been satisfied with the relative pay rates in the department. In my company there are some 2,000 or more jobs that are so rated.

TIPS AND QUIPS

Sewage Station Joins the Country Club Set

The attractive brick house on the large tree-shaded, grassy corner plot (Figure 1) is one of the showplaces of the country club district of Fairway, Kans., residential suburb of Kansas City. The adjoining homes sell for $20,000 and up and, although No. 5700 cost a lot more, it blends nicely and unpretentiously with the neighboring dwellings.

The Fuller brush man, home seekers, and many of the newer neighbors don't know it yet, but No. 5700 is a sewage pumping station with three pairs of big pumps handling an average of 3 m.g. of sewage a day.

The large and rapid expansion of suburban areas near Kansas City has necessitated combined effort to meet such problems as sewage disposal. In 1945, Mission Township Main Sewage District No. 1 had a population of 11,500 and plans were drawn for a sewage collecting system, pumping station, and treatment plant designed to serve 15,000 people. No one anticipated the tremendous influx which raised the district's population to an estimated 36,000 in 1951. The system, planned for 15,000, somehow managed to serve 22,000 and plans were drawn swiftly to duplicate facilities and double capacity.

In planning the original system, one major problem was the location of the main pumping station. The logical place for it was the lowest point in the district, in the midst of Fairway's attractive country club residential district. The solution to the problem was a masterful piece of architectural design, which successfully camouflaged the sewage station and made it a positive asset to the community in appearance as well as utility.

No one lives at No. 5700, not even an operator. The big station is completely automatic in all normal operations. Usually the door is closed and

FIGURE 1.—The attractive brick house on the corner conceals its identity from the passer-by. There is no evidence of its real function as the main sewage pumping station serving a district of 36,000 population.

no one is "at home." Only when the door is opened does one see that this is no ordinary house. But it is reported that the adjoining householders look on No. 5700 as one of the best neighbors possible!

Not an Extra

Elsewhere in this "Corner" a partial report on the "Operators' Forum" at the New York meeting contains the discussion on provision and operation of laboratory facilities at sewage treatment plants.

The whole substance of that discussion is neatly summed up by S. R. Kin, Sanitary Engineer, Indiana State Board of Health, who says: *

"The sewage plant laboratory is often considered 'optional equipment.' To the experienced superintendent the laboratory is about as 'optional' as the steering wheel is to the driver of an automobile."

* S. R. Kin, "Sewage Treatment Plant Laboratory." *Sewage Gas*, **15**, 2 and 3, 25 (1952).

Portable Dissolved Oxygen Analyzer

A new dissolved oxygen analyzer (Figure 2) is claimed to be ideal for field or laboratory use in determining the oxygen content of sewage, brines, and other liquids, and not to be subject to interference by dissolved iron, calcium, magnesium, or organic matter. The instrument, entirely self-contained in a carrying cabinet, operates on readily obtainable long-life batteries. It utilizes an amperometric principle in which minute traces of dissolved oxygen are reduced at a rotating platinum electrode. The electrode assembly is mounted on a detachable frame and can be used for other analyses if desired.

According to the manufacturer, the Dorber Co., 7741 W. Palatine Ave.,

FIGURE 2.—Portable dissolved oxygen analyzer for field and laboratory use.

Chicago 31, Ill., complete interference-free determinations, correct within 5 per cent for most solutions, can be made in only 10 to 30 sec. Selling price is less than $500.

Paint Insecticide Mix

A paint insecticide mix designed to kill roaches, flies, mosquitoes, and other pests has been developed. The product is claimed to be applicable to any area and to be effective for the life of the paint. Called "Holowak No. 333," the insecticide is an odorless powder that can be mixed with any type of water, oil, or dry paint with gloss, semi-gloss, or satin finish. It will not harm human beings or animals, according to the manufacturer, Holloway Industrial Products Co., Inc., 550 Fifth Ave., New York 36, N. Y.

Comments on Sewage Irrigation

In a recent report to the Texas State Department of Health, J. T. Sparks, Engineer Assistant with the Engineering Division, reveals some interesting facts on sewage irrigation in the Mitchell Lake area of that state.

Mitchell Lake, located about 12 mi. southwest of San Antonio, is an artificial lake about 680 acres in area. It receives San Antonio sewage in various stages of treatment, as well as the runoff from a small watershed. Irrigation water is taken from the canal that leads from the sewage plant to the lake, and from other canals supplied by the lake.

The different kinds of sewage waters used for irrigation are spoken of by most farmers and ranchers who use them, as follows:

White—final effluent, clear.
Brown—activated sludge.
Black—digester supernatant.
Green—Mitchell Lake Water.

Many farms and ranches use the sewage waters for irrigation. The report covers a study made of four of the largest (total acreage 2,740, of which 1,827 acres were irrigated).

On the first ranch, almost entirely devoted to beef production, the operator stated that without sewage irrigation, his hay production would probably be only about one-fourth its present yield. On a purely non-scientific basis, he assesses the benefits received from sewage irrigation as greater than those from use of ordinary water.

On the second ranch, 150 acres of irrigated permanent pasture support an average of 2 cows per acre, whereas without irrigation, it would support only 1 cow per 30 acres. Mitchell Lake water is used on pastures in both summer and winter. Digester supernatant is used principally in winter on cropland; it has a tendency to "burn" the crop in hot weather. Final effluent is used principally in summer. This operator likes to use digester supernatant, final effluent, and Lake Mitchell water mixed, although he thinks that digester supernatant has more fertilizer value than the others. No distinction is made by this operator between digester supernatant and activated sludge. Of the 500 acres irrigated, about 250 acres are supplied with Lake Mitchell water and the remainder with supernatant and activated sludge.

On the third farm, with 227 acres under irrigation, about one-half of the total sewage water used is final effluent. The remainder is digester supernatant. No lake water is used. This operator prefers digester supernatant to other types of sewage waters, although supernatant and final effluent are used during any season, on any tract, and on any crop as they are available in the canal. The flooding system of irrigation is practiced. The operator feels that the sewage water is safe to use for stock water and presents no health hazard to livestock by reason of its use for irrigation.

On the fourth farm, with 200 acres under irrigation, preference is given to digester supernatant over the other forms available. Final effluent is used when supplied, and some lake water is used. This ranch is equipped with both flood and sprinkler irrigation systems. Pastures will support 1 head per acre for about 8 months of the year.

Safety from Head to Toe

A new SAF–HED–HAT, manufactured by the United States Safety Service Co., Kansas City, Mo., is claimed to fill a need for a more rugged safety hat with longer life that is still light in weight and comfortable to wear. Fiber Glass, the material used, is highly resilient and durable, and will not split, crack, or deform. The cradle can be quickly and easily adjusted to fit all head sizes.

At the other extreme, a new 10-in. rubber bootee with patented suction sole and steel safety toe box is the latest product in wet-floor safety equipment. Besides keeping the feet dry in areas where the regular knee-boot is too clumsy and where rubber shoes get soaked, the Neoprene-coated bootee provides corrosion resistance against fats and oils. Tested to withstand impacts of more than a ton, the safety toe box insures reduced foot injuries, even in hazardous wet conditions. Further information on the bootees is available from the manufacturer, Lehigh Safety Shoe Co., Allentown, Pa.

That's the Trick!

Superintendent Robert Carlin, of Pensacola, Fla., takes a real pride in his job in that thriving city, as attested by a sign on the rear of his family car reading: "Superintendent, Sewage Treatment Plants."

But, according to a recent issue of *The Overflow*, newsletter of the Florida Water and Sewage Works Operators Association, the sign also gives him a certain license for parking wherever he pleases—that is, if he can find the space!

More Manhole Accidents

Two more cases—one fatal—of asphyxiations in manholes have come to our attention through the medium of the *Safety News Letter* of the Public Employee Section, National Safety Council.

In one case a Connecticut State Highway Department employee in the course of routine survey work entered a manhole to determine pipe sizes and elevations. According to the account, "apparently either marsh gas or hydrogen sulfide was present and he became unconscious from lack of oxygen. Another employee entered the manhole to assist the stricken man and was himself affected, but managed to get out. The injured employee was in the manhole for approximately 10 min. before a rope could be secured to extricate him. Fortunately there was no fatality, although both employees were hospitalized."

The fatality occurred when an employee of a private concern entered a Minneapolis, Minn., manhole to operate a water valve for a construction job. Cause of the accident is not given in the reported warning to city employees, but is vaguely referred to as "monoxide gases, other gases, or lack of oxygen." This same warning concludes with a note that might well be heeded by all, as follows:

Make Proper Tests!
Make the Job Safe!

Don't take chances because it seems safe. One accident is all that is necessary sometimes to make your kids orphans and your wife a widow. Don't let carelessness hospitalize you.

Use proper equipment!
Use your head!
Be safe!

Reviews and Abstracts*

"Information Please" on Sludge Digestion —A Panel Discussion. *Jour. Boston Soc. Civil Eng.*, **39**, 284 (1952).

In this panel discussion, topics briefly discussed included fixed *vs.* floating covers, P.F.T. scum blanket treatment, methane bacteria effect on conditioning of digested sludge, and ratio of gas produced to pounds of solids digested. (Theoretically 1¼ lb., or about 8.6 cu. ft. of gas, are generated per pound of solids added; and 11.8 cu. ft. of gas per pound of volatile solids added.) Grease disposal is a matter of whether the grease matter is digestible. Also, grease can be incinerated. Geographical differences exist in digestion rates. Detention of solids in long trunk sewers may favor development of hydrogen sulfide. Digester operation should maintain an even temperature, but thermophilic digestion is advantageous. Fertilizer value is largely destroyed by digestion. Many believe there is no merit in having more than two stages of digestion in series. The problem is to find a method by which the wastes may arrive uniformly in the digester on a continuous basis, instead of intermittently.

LANGDON PEARSE

Design of the Bucklin Point Sewage Treatment Plant. BY J. S. BETHELL, JR. *Jour. Boston Soc. Civil Eng.*, **39**, 320 (1952).

The estimated population to be served by the Bucklin Point plant of the Blackstone Valley (R.I.) Sewer District Authority in 1975 will be 158,600, with a flow of domestic sewage of 17.8 m.g.d. The industrial wastes, mostly textile, are estimated at 29.4 m.g.d. The total flow will be 47 m.g.d. The treatment facilities include Parshall flumes; mechanically-raked bar racks with screenings grinders; mechanically-cleaned grit conveyors, washers, and grit storage facilities; preaeration tanks equipped with swing-type diffusers; mechanically-cleaned settling tanks; chlorination facilities; sludge digestion tanks; and elutriation and dewatering equipment. The sewage flows through the plant by gravity. The plant is described in detail, with design data and a list of manufacturers supplying equipment.

LANGDON PEARSE

Limitations of Standard Bacteriological Methods in Evaluating Sanitary Quality of Water. BY F. W. GILCREAS. *Jour. New England Water Works Assn.*, **66**, 167 (1952).

The author confines his attention to the bacteriologic procedures for examination of water from 1890 on, sketching the changes in the definition and use of *B. coli* tests, and the development of the coli-aerogenes group, later termed the "coliform group." The changes in culture media and the use of confirmatory tests supplementary to the presumptive tests are noted.

The one great weakness of the bacteriologic examination of water has been the time required for the test. The tendency has been to shorten the technique. In the 10th Edition of "Standard Methods," now in preparation, the use of lauryl sulfate tryptose broth will be recommended for certain waters in place of beef-extract lactose broth in the presumptive test, but positive presumptive tubes must be confirmed by subsequent inoculation into brilliant-green lactose bile broth or other confirmatory media.

The significance of the aerogenes section of the coliform group merits attention. Special methods for its differentiation are included in "Standard Methods," but the development of new differential tests for the coli and aerogenes sections would not aid in evaluating the sanitary quality of water. For appraising the quality of

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

public water supplies—treated or untreated—the coliform group is useful.

Presently established bacteriologic tests do not provide for the detection and enumeration of microorganisms which ferment lactose slowly, producing gas only after 72 or 96 hr., or longer.

The need for a quantitative method for the measurement of pollution of water was early recognized. After trials of various methods of expressing the coliform densities, the M.P.N. index has been generally accepted. This is the number of coliform microorganisms which more probably than any other number would yield the observed laboratory results.

The author states that "in the examination of waters from swimming pools or bathing beaches, the coliform group is of little importance, since the significant bacterial contamination of the water may not be intestinal in origin, but associated with other body discharges."

Too little is known of the quantitative significance of fecal streptococci and other types.

The quantitative significance of virus in water is unknown.

The use of plate counts at 20° C. has been dropped and apparently the use of 37° C. count (now made at 35° C.) is on its way out. The author emphasizes that "the validity of examinations of water is predicated upon the integrity of the sample" and discusses the effect of time and refrigeration.

No change in the requirements following the collection of samples will be incorporated in the 10th Edition.

"The standard procedures for the examination of water are not finally established; they have definite limitations which must be understood thoroughly." The value of laboratory work is greatly reduced if the individuals who interpret the results are not thoroughly acquainted with the limitations. LANGDON PEARSE

1951 Annual Report. Interstate Sanitation Commission (1951).

The 1951 report of the Interstate Sanitation Commission, servicing parts of New York, New Jersey, and Connecticut, indicates continued progress in its pollution abatement program. During the year, 12 sewage treatment plants went into operation, designed to treat the sewage of 850,000 people, thereby raising the quantity of sewage treated in the district to 590 m.g.d. and the population served to 4,825,000.

The Industrial Waste Inventory is completed, showing a discharge from 306 plants of 1,675 m.g.d. along the shores of the district, of which some 515 m.g.d. are contaminated wastes, and 1,160 m.g.d. are uncontaminated. The contaminated wastes are estimated to contain 385,000 lb. of suspended solids, 95,000 lb. of acid, 66,000 lb. of toxic materials, and 101,000 lb. of grease and oil daily. The population equivalent is about 2,100,000. These wastes are concentrated in six locations. All the waters of the District are tidal, and of several types.

In the last decade, the population of the central counties has increased 5.2 per cent, whereas the bordering peripheral counties increased 20.8 per cent.

LANGDON PEARSE

Fourth Annual Report. New England Interstate Water Pollution Control Commission. 34 pp. (June 30, 1951).

The Commission suggests 5 classifications of waters according to the highest use and the report outlines the state water pollution control programs. The problem of oil pollution has become serious in certain harbors and tidal estuaries. Serious spills occur occasionally. The progress on sewage and industrial waste treatment has been retarded somewhat by state laws which limit municipal indebtedness, as well as by tax problems in industry and restrictions of national defense. The progress in general is encouraging and is described for each state in some detail. Details are given on advances (under Public Law 352 of 81st Congress) for planning sewage works, and grants for industrial waste pollution studies made by the U.S.P.H.S. (totaling $104,100) and research on industrial wastes in the New England area ($10,000). A tentative plan for classification of waters, and the standards are outlined in appendices. LANGDON PEARSE

Auckland Metropolitan Drainage Board—Annual Report for Year Ending June 30, 1951.

The estimated population as of April 1, 1950, was 268,390 on an area of approximately 61 sq. mi. The main sewerage works includes a main sewer (about 8 mi.

long); branch sewers (about 19.2 mi. long); pumping station, and Orakei disposal works (screens, grit chamber, storage chamber, and outfall); five smaller tanks, and outfalls. A considerable portion of the District is unsewered. The preliminary work on new developments is briefly described, including experimental work on the application of anaerobic digestion (2 days at 80° F.) to meat-packing wastes, followed by secondary treatment in oxidation ponds for 3 to 4 days; and the dewatering of sludge. The high cost of ferric chloride is an objection to vacuum filtration. Pressure cooking is being tested.

In the treating of the meat-packing wastes, the following results are indicated:

	Meat Wastes		Oxidation Pond Effluent (p.p.m.)
	Raw (p.p.m.)	Digested (p.p.m.)	
5-day B.O.D.	1,553	134	53.2
Ammoniacal N	32	147	60.
Susp. solids:			
Total	1,275	53.6	Negligible
Volatile	1,008	28.0	Negligible
Non-Volatile	267	25.6	Negligible

Based on the B.O.D. test, purifications effected include: digested waste, 91.4 per cent; oxidation pond effluent, 96.5 per cent. Gas produced amounted to 219,000 cu. ft. per m.g., (Imp.) of waste.

In the summer, the meat wastes average about 3.25 m.g.d. (Imp.), with an alkalinity of 1,050 p.p.m.; chlorides (as Cl) 980 p.p.m.; B.O.D. 1,994 p.p.m.; and suspended solids 1,050 p.p.m. of which 722 p.p.m. are volatile. LANGDON PEARSE

The Pollution of the Bzura River. By IRENA CABEJSZEK, ZBIGNIEW MALANOWSKI, AND STANISLAW WŁODEK. *Gaz, Woda i Tech. Sanit.* (Poland), **26**, 6, 162 (1952).

During June 19–27 and November 5–10, 1951, a survey was made of the pollution of the Bzura River, a tributary to the left bank of the Vistula River. Samples were collected for bacteriological and biological examinations and physicochemical analyses from 28 stations along the 155-km. stretch of the river. The purpose of the November survey was to determine the effect of the discharge of wastes from four beet sugar processing plants, which were in operation at that time. Other industrial plants located on the watershed and discharging wastes to the Bzura River included two chemical plants, a pharmaceutical plant, two tanneries, and a textile plant. In addition, sewage wastes are discharged from communities along the river. Acid conditions are produced near the headwaters of the river and continue for a stretch of approximately 30 km. In this zone no biological organisms were found, although there was evidence of bacteriological pollution. During the summer months the highest 5-day B.O.D. was 10 p.p.m., whereas in November, with the sugar plants in operation, the B.O.D. increased to 99.6 to 108 p.p.m. As a result of the pollution at the headwaters of the Bzura River, recovery does not take place until approximately one-half of the length of the stream has been traversed (75 km.) Recovery is somewhat slower during the colder months. During the last 75 km., before confluence with the Vistula River, the B.O.D. does not exceed 10 p.p.m., and the oxygen saturation value ranges from 40 to 137 per cent during the summer and averages about 65 per cent during the colder months. The authors suggest that the municipal wastes should receive some treatment before discharge to the river and that special studies be made of the industrial plant wastes to provide pretreatment before discharge.

CONRAD P. STRAUB

Treatment of Paper Pulp Wastes. By JERZY GAŃCZARCZYK. *Gaz, Woda i Tech. Sanit.* (Poland), **26**, 7–8, 212 (1952).

A review is presented of various methods for the treatment of white water from the manufacture of paper. The problem is discussed from the standpoint of the reuse of water (closed systems), methods for treating white water, and analytical control. Under methods for treating white water, the author discusses separation by horizontal and upflow (Marx-type separator) sedimentation, filtration (Waco-, Wagner-, Fuelner-type units), flotation (Sveen-Pedersen, Wolf, Adka, and Savalla save-alls), coagulation, combined save-all and coagulation treatment, and biological treatment. In sedimenta-

tion units settling velocities for ground fibers are given at 8 mm. per sec., and for cellulose fibers at 0.6 to 0.7 mm. per sec. for approximately 75 to 80 per cent of the fibers and at 0.26 to 0.3 mm. per sec. for 20 to 25 per cent of the fibers. It is also pointed out that this method of treatment does not result in a reduction of the B.O.D. or the oxygen consumed value of the white water. Up to 95 per cent reduction in the suspended solids is reported for these units, whereas with flotation-type equipment removals up to 99 per cent may be obtained. In conclusion, the author stresses the need for parallel laboratory studies, suggesting Imhoff cone studies of the settling characteristics of the suspended matter, and B.O.D. or oxygen consumed studies of the dissolved organic fraction of the waste. CONRAD P. STRAUB

Studies on Sewage Treatment by Flotation Without Detergents. BY M. NEWE, J. SCHMIDT, AND A. SZNIOLIS. *Gaz, Woda i Tech. Sanit.* (Poland), **26**, 7–8, 194 (1952).

A previous paper by the authors (see abstract THIS JOURNAL, **24**, 9, 1203; Sept., 1952) showed that (a) the use of a wide variety of detergents did not assist in the treatment of sewage by flotation, (b) the addition of detergents combined with acidification resulted in high removals of solids by flotation, and (c) the addition of alum and acidification gave better removals than did similar treatment with detergents. These findings led to additional studies to determine (a) the application of flotation and coagulants as an aid to rapid coagulation; (b) the effect of acid on the process in the hope that it might be eliminated, since it limits the use of the process on a practical basis; and (c) the possibility of using flotation in the treatment of acid wastes. As before, the studies were carried out with municipal sewage which had settled for 15 min. Studies on combined flotation and coagulation with variable amounts of alum showed no effect on the removal of contaminants. In studies to determine the optimum coagulant dose in an acid medium with flotation, removals were excellent and were independent of coagulant dose. By reducing the coagulant (alum) dose to practically zero, similar good results were obtained. This led to a study to determine whether the alum was necessary in the treatment or whether similar removals could be obtained with acidification alone. Accordingly, the wastes were acidified and treated by flotation with the following removals: suspended solids 96 per cent, oxygen consumed 71 per cent, and 5-day B.O.D. 67 per cent. Using HCl, H_3PO_4, H_2SO_4, and CH_3COOH, studies were carried out to determine optimum pH ranges for removal of suspended solids by flotation. The results showed that the optimum pH range for HCl was 2.3 to 3.6 with a suspended solids removal of 97 to 100 per cent, for H_3PO_4 the pH range was 2.4 to 3.6 with a removal of 96 to 100 per cent, for H_2SO_4 the pH range was 2.0 to 3.0 with a removal of 94.6 to 100 per cent, and for CH_3COOH the pH range was 3.4 to 4.4 with a removal of 94.0 to 95.8 per cent. CONRAD P. STRAUB

Summary Report on Water Pollution: Southwest-Lower Mississippi Drainage Basins. U. S. Pub. Health Service Publ. No. 160 (1951).

Sewage treatment projects are recommended at 517 municipalities and a large number of industrial locations in an area extending to 11 states. Initial cost of the municipal projects is estimated at $50,000,000. No estimate is given for industrial waste treatment requirements and costs. Municipalities need 132 new treatment plants, enlargements or additions to 251, and replacement of 14 plants. Known industrial needs include 43 new plants, 20 enlargements or additions, and replacement of one plant.

No projects are needed at 289 municipal and 42 industrial locations, but project needs are undetermined for 40 municipalities and 979 industries.

H. P. ORLAND

Air Pollution Abatement Manual, Bibliography. Manufacturing Chemists Assn., Washington, D. C. 57 pp. Price, 50 cents (1952).

Chapter 12 of the manual, published in separate form for loose-leaf use, is an extensive bibliography on air pollution, covering causes, effects, control, and abatement methods. More than 1,500 literature references form the present compilation, listed under the principal headings of Biological, Legislative, Tech-

nical, Standards, Education, and Miscellaneous.

Air Pollution Abatement Manual, Bibliography Appendix. Manufacturing Chemists Assn., Washington, D. C. 21 pp. Price, 35 cents (1952).

The first of a series of appendices to be issued semi-annually to keep the reference material of Chapter 12 as up-to-date as possible. References in Appendix I include those for the first half of 1952.

H. P. ORLAND

The Mechanism of Sewage Purification by Trickling Filters. By ISAMU HORASAWA. *Jour. of Plumbing and Heating Contr. Assn.*, 6, No. 4 (1952).

The author recognizes the importance of other organisms besides bacteria (such as the protozoa) in the purification of sewage by trickling filters. He classifies the organisms as follows: (a) filter film organisms, (b) film surface organisms, (c) filter cleaning organisms. In normal sludge the film surface type predominates and comprises more than 90 per cent. As the filter becomes overloaded or otherwise unbalanced, the organisms of non-film surface type increase. These latter forms also predominate during the initial stages of operation of a new filter.

H. HEUKELEKIAN

Clarification and Flocculation of Sewage. By G. MULLER-NEUHAUS. *Gesundh. Ing.*, 73, No. 7/8, 132; No. 11/12, 194 (1952).

This is a theoretical discussion of single factors affecting settleable solids removal and the relation between settling and flocculation. Coagulation of waters containing finely divided suspended solids is essential. Coal and clay particles of 1 to 10μ diameter in Emscher River water settle at an average rate of 0.01 meters per hour and must be coagulated. Weak sewages do not coagulate as well as strong sewages. With sufficient coagulation, particles can be formed with a settling rate of 1.0 m. per hr. or more. When a certain particle size has been reached, particle movement has no further effect. In settling tanks the coagulation time and settling time should be considered separately. If the coagulation time is considered to the critical floc size the flocculation time is determined in the first section and the settling time in the second section of the tank. Molecular (perikinetic) coagulation occurs only with large initial concentrations and only during a short period. For clarification of sewage the streaming (orthokinetic) coagulation is important. In orthokinetic coagulation the agglomeration occurs only through settling of large particles; non-agglomerated particles are, in general, not coagulated because of the lack of time. Vertical mixing of the mass enhances removal of finely divided material. Since the effect of orthokinetic coagulation is related to the size of the particles (small particles are only bound to other small particles and large to large) the critical floc size can be enlarged by choice of mixing velocity, hence better and more rapid settling. W. RUDOLFS

Biological Studies on the Purification of Sewage by Activated Sludge. VI. Removal of Dissolved Solids. By ISAMU HORASAWA. *Jour. Water and Sewage Works Assn.* (Japan), 200, 23 (1951).

The removal of dissolved solids from sewage by activated sludge is very slow in contrast with the removal of suspended solids. Only 20 per cent of dissolved solids are removed after 2-hr. aeration. It is concluded that removal of dissolved solids is carried out by means of biological absorption, as contrasted with physical absorption of suspended solids. The growth of floc is primarily brought about by dissolved solids. H. HEUKELEKIAN

Effect of Supersonics on Sewage and Sludge. By W. HUSMANN. *Gesundh. Ing.* 73, 7/8, 127 (1952).

Laboratory experiments are described for 15- and 30-min. treatment of raw sewage, fresh solids, and digested and activated sludges. In domestic sewage the amounts of settleable solids are reduced on treatment, because part of the colloidal particles disintegrate and will not settle in a reasonable time. The strength of the sewage, measured with $KMnO_4$, increases materially. Dewaterability of fresh solids and digested sludge is not increased. Activated sludge is deteriorated, loses its good settleability, and becomes finely divided so that already purified sewage effluent becomes much poorer (higher oxygen consumption).

W. RUDOLFS

Keeping Sewage Fresh in Sewers. By Wilhelm Müller. *Gesundh Ing.* 9/10, 164 (1952).

Sewage can be kept fresh only if it can obtain oxygen from the sewer atmosphere. During dry-weather flow the depth of sewage in any sewer should not exceed 14 cm., irrespective of the sewer cross-section. Combined sewers are better than separate ones because during dry weather more air is available above the sewage. In separate sewers the air space should be ½ to ⅔ of the diameter. Collecting sewers with high flows should be short. In pressure lines the maximum detention time should be 1 hr. Supplying sewers with air or oxygen, or use of chlorine, may be helpful and economical. In drainage ditches for sewage farming the water level should be low and the velocity high. Five-fold dilution with surface water before entering distribution lines is feasible. Pre-settling and sewer cleaning helps.

W. Rudolfs

Sewerage and Sewage Disposal in Sub-Tropical Countries with Special Reference to South Africa and Mauritius. By E. J. Hamlin. *Proc. Inst. Civil Eng.*, 1, 561 (1952).

In showing the differences in practice between Great Britain and sub-tropical countries, the author stresses the importance of details in the design of sewage works for the latter. As a general policy, mechanization is avoided as much as possible.

The type of sewage to be treated depends a great deal upon the diet of the population concerned—a diet which ranges from one of entirely carbohydrate intake of the Bantu to the emulsified blood and milk regimen of the Masai.

The African laborer is migratory; he is frequently a carrier of poliomyelitis and a sufferer from intestinal infections caused by *Ascaris* (round worm). Special precautions are necessary to deal with the ova of these diseases.

The effect of diet on sewage disposal is, briefly:

1. European concentrated diet:
(a) 20 to 30 grams of dry fecal matter per day.
(b) 2 to 4 grams of fat per day.
2. European brown bread diet:
(a) 40 to 53 grams of dry fecal matter per day.
(b) 2 to 4 grams of fat per day.
3. African carbohydrate diet:
(a) 60 to 100 grams of dry fecal matter per day.
(b) 6 to 15 grams of fat per day.

Consequently, in South Africa the sludge capacity provided is about 2.5 cu. ft. per European and 5 cu. ft. per non-European. Water supply varies with the scarcity of water. Many cities report 15 g.p.d. (Imp.) or less per capita, to which 7.5 to 9 g.p.d. (Imp.) is added per capita for sewerage.

Langdon Pearse

Annual Report of the Commissioner of Public Works of the City of Fitchburg, Mass., 1951.

This annual report contains a section on the operation of the sewage disposal plant by W. Lamothe for the year ending December 31, 1951.

The population (U. S. Census, 1950) was 42,691, of which 42,000 are estimated to contribute sewage. The sewage treated averaged 104.5 g.p.c.d. The settling period in the Imhoff tanks averaged 5.2 hr. The trickling filters treated an average flow of 2.36 m.g.d. 10.5 nozzles were cleaned daily. 1.86 acres of filters were used out of 2.12 acres available. The sludge drying beds (area 31,350 sq. ft.) were cleaned twice, with a removal of 725 cu. yd. of air-dried sludge. The total volume of Imhoff tank and secondary sludge was 890,000 gal., of which 575,000 gal. went to the sludge drying beds and 165,000 gal. went to a lagoon. From the secondary tanks, 150,000 gal. was delivered to two drying beds (total 3,300 sq. ft. area). Daily 3.6 cu. ft. of scum and skimmings was removed from the Imhoff tanks. No analytical data are given.

Langdon Pearse

The Influence of Chromium Compounds on Activities of a Sewage Treatment Plant. By R. Vrÿburg. *Chemisch Weekblad*, **48**, 689 (1952).

Mixed sewage and industrial wastes containing 250 p.p.m. chromium compounds (as Cr) caused difficulties in a treatment plant. The settled fresh sludge contained 0.4 per cent Cr on a dry basis; the primary digestion tank sludge, 1.2 per cent; the secondary digester sludge, 2.0 per cent; the humus in the trickling filters, 2.8 per cent; and the final settling tank sludge, 1

per cent. Laboratory experiments showed that gas production was reduced by one-half with 500 p.p.m. Cr and to one-sixth with 1,000 p.p.m. Cr.

WILLEM RUDOLFS

Problems in Sewage Farming. BY FRANZ SHREIER. Berichte der Abwassertechnischen Vereinigung e. V., No. 2, 118 (1950).

The problems to be considered in sewage farming are pretreatment, changes in farming methods, zoning of urban areas, hygiene, biology, and economics. The advantages of mechanical pretreatment are less wear and tear on pumps; no sludge deposits in ditches and pressure sewers; no clogging of the soil; ability to regulate sewage supply with drainability of soil; ability to rest drainage fields if discharge to a stream is possible, and removal of germs and weed seeds. Fertilizer value losses are only about 1 per cent. Digested sludge, digester supernatant, and sludge drainage water may also be utilized. Pretreatment is therefore considered imperative. Introduction of sewage farming is frequently opposed by the farmer. Changes in farming methods are radical and involve new capital investments. Zoning of urban areas is not economical near larger cities where land uses for industry, residence, etc., are more important. Hygienically, urban areas should not be exposed to odors; sewage farming should not be permitted near water treatment plants; sewage distribution should cease at least one week before harvesting; potato fields should not be sprayed after flowering, and vegetable fields may not receive sewage after planting. Biologically, continuous fertilization as exemplified by sewage farming is better than periodic fertilization. For a city with a population of 400,000, requiring 12,000 acres, sewage disposal by farming costs about four times more than sewage disposal by complete treatment. This comparison does not consider the fertilizer value of the sewage. Thus, sewage farming is practical only when the cost per capita is reasonable. Sewage farming for large cities is not advisable, but it may be very practical for small towns and villages. In sewage farming, irrigation is the best assurance of sufficient purification. Spraying onto grazing areas is hygienically, biologically, and economically the best means of sewage utilization.

Discussion of the paper by various people brought out the following points:

Other disadvantages of utilizing raw sewage are H_2S production, change in soil composition, loss of digester gases, and reduction in available soil nitrogen by combination with fresh sludge. When considering sewage farming, factors of importance are industrial wastes, ground-water shortage, pollution of surface waters, need for sewage as fertilizer *versus* that for irrigation, use of digested sludge and digester supernatant, prevention of diseases, power requirements for pumping, and use of pipes *versus* open ditches. Courses of action suggested are use of raw sewage, pretreatment of sewage, sludge digestion, complete treatment with use of receiving waters, and complete treatment utilizing digested sludge and digester supernatant only. The long-run economic effect is the deciding factor.

P. K. MUELLER

The Treatment of Pickle Liquors. BY A. R. L. CHIVERS. *Water and San. Eng.*, **3**, 6, 213 (1952).

This paper deals with the requirements for pickle liquor waste treatment from small galvanizing plants using hydrochloric or sulfuric acids, reviews various methods of treatment, and describes a few neutralization and recovery plants in Britain.

One of the examples cited uses carbide waste for neutralization of hydrochloric acid pickling liquor. This plant treats 200 gal. (Imp.) of strong pickle liquor per week. The neutralization is carried to a point of complete precipitation of iron, as indicated by ferrocyanide test. The treated liquor is discharged into the sewer. In another plant the wash water and the spent liquor are treated together with carbide waste, the treated liquor being recirculated in the rinse tanks so that there is hardly any discharge into the sewer. The precipitated iron is separated in filter presses. The filter cake, containing 50 per cent moisture, is used as landfill material.

In another plant pickling liquor containing 2.5 per cent HCl and 8.5 per cent iron with some zinc is stored, settled, and diluted with 8 volumes of surplus rinse water and treated with lime until all the iron is precipitated out, as indicated by ferrocyanide test. The treated liquor,

with the precipitate, is discharged into the sewer.

The recovery of sulfuric acid is practiced in another plant by batch crystallization of copperas. H. HEUKELEKIAN

Dewatering of Sewage Sludge by Electro-osmosis. By L. F. COOLING, E. E. JONES, AND A. E. S. PETTET. *Water and San. Eng.*, **3**, 7, 246 (1952).

The study was undertaken to determine the effect of passing a current on the dewatering of digested sludge. Digested sludge responds to treatment with electro-osmosis. The electro-osmotic permeability was 0.006 gal. per sq. ft. per hr. per volt per inch. The quantity of water removed by electro-osmosis is directly proportional to the quantity of electricity transported, the constant being 0.02 gal. per ampere-hour. The thinner the sludge layer, the more economical in current is the process. In the initial stages the power required to give a certain rate of yield of water increases directly with thickness. If the initial rate could be maintained, the energy required to produce a given low average water content would increase with the square of the thickness. A practical difficulty is the formation of a dried crust on the anode. This reduced the electrical efficiency of the system. The consumption of electricity in the pilot tests was so high that application of the process under practical conditions would be uneconomical. In addition to the cost of power, there would be the cost of replacement of corroded anodes and labor to place the electrodes in the beds. H. HEUKELEKIAN

Treatment of Waste Waters Containing Hydrogen Peroxide, Hydrazine, and Methyl Alcohol. By G. E. EDEN, A. M. FREKE, AND K. V. MILLIOURNE. *Chem. and Ind.*, 1104 (1951).

This paper deals with the treatment of wastes from the manufacture of rocket motors containing hydrogen peroxide, hydrazine hydrate, methyl alcohol, nitric acid, and some fuel oil.

Toxicity of the individual ingredients of this waste to fingerling rainbow trout was determined. It was found that concentrations of hydrogen peroxide below 40 p.p.m. had no effect in 48 hr. Above this value toxicity increased linearly with concentration. Hydrazine hydrate was found to be very toxic. At 0.7 p.p.m. fish lost equilibrium in less than 24 hr. Methyl alcohol up to 8,100 p.p.m. had no apparent effect on fish in 24 hr. Formaldehyde at 10 p.p.m. did not harm fish in 3 days; at 50 p.p.m. the fish were killed in 1 to 3 days.

Hydrogen peroxide in the waste disappeared appreciably at pH 11.0. The addition of catalysts at this pH value increased the rate of disappearance of peroxide. Calcium permanganate was more effective in this respect than copper sulfate. Methyl alcohol (780 p.p.m.) reduced the rate of disappearance of peroxide at pH 11.0 and in the presence of catalysts.

The oxidation of hydrazine by hydrogen peroxide in the presence of methyl alcohol was only partial at a pH value of 11.0 and in the presence of catalysts, when the mixture was aerated. In the absence of methyl alcohol under otherwise similar conditions the removal of hydrazine by peroxide was complete.

The method of treatment recommended for this waste on the basis of experimental work was (1) removal of immiscible liquids in an interceptor; (2) equalization; (3) batch treatment in tanks provided with mechanical agitators, involving neutralization by lime to pH 7.0 if the wastes are acidic, addition of 1 p.p.m. Cu as copper sulfate, stirring to remove hydrazine, addition of lime to pH 11.0 and manganous chloride to give a concentration of 4 p.p.m. Mn, stirring until the peroxide is decomposed, and, finally, removal of precipitated salts of copper and manganese. If the methyl alcohol content of the waste is high, giving a high B.O.D. in the treated effluent, a further stage of biological treatment would be necessary.

H. HEUKELEKIAN

Treatment of Waste Waters from the Manufacture of Penicillin. By G. E. EDEN AND G. F. LOWDEN. Reprinted from *Manuf. Chem.* (Great Britain) (Apr., 1952).

A penicillin manufacturing plant in Great Britain did not have a convenient means of disposing of the effluent except a municipal plant treating the sewage of 5,500 people by sedimentation and trickling filters. The discharge of the waste into the municipal plant would have increased the load two or three times. A series of experiments was undertaken to

determine (a) what degree of pretreatment at the factory would be necessary before discharge to the municipal disposal plant and (b) what quantity of waste could be accepted by the municipal treatment plant without detriment to the quality of effluent.

Laboratory experiments were conducted with biological filtration of the waste. The waste, with an average B.O.D. of 4,900 p.p.m., was diluted to 275 p.p.m. B.O.D. with water. With rates of application of diluted waste of 90 gal. (Imp.) per cu. yd., effluents with less than 10 p.p.m. B.O.D. were obtained. The beds ponded, however, presumably because of absence of fly larvae and other scouring organisms.

Recirculation of filtered effluent was tried without other kind of dilution of the waste. The results showed that at B.O.D. loadings of about 0.5 lb. per cu. yd. per day the effluent had a B.O.D. of 30 p.p.m. Prior to application on the trickling filter, the spent liquor, aerated for a period of 24 hr. after seeding with 50 per cent by volume of previously aerated liquor, gave considerable B.O.D. reductions. The aerated settled liquor was then applied to the recirculated filter and at a loading of 0.6 B.O.D. per cu. yd. per day, the B.O.D. of the effluent averaged 60 p.p.m. It was more difficult to produce an effluent of high quality after preliminary treatment by aeration.

The effect of controlled discharge of spent broth to the sewage disposal plant was then studied. 3,000 gal. of waste was discharged at a uniform rate during the night, when the load on the plant was light. The B.O.D. of the settled effluent from the filters was nearly constant over the 24-hr. period at about 10 p.p.m., as a result of controlled discharge of waste at night. If the plant was modified so that filters could be recirculated, on the basis of the experimental work cited, at a B.O.D. load application of 0.4 lb. per cu. yd. per day the filters could handle 12,000 gal. of spent broth per day. With the construction of an additional filter and operation with recirculation, the plant could handle 19,000 gal. of spent broth per day in addition to the sewage flow.

H. HEUKELEKIAN

Preliminary Treatment of Sewage. By L. B. ESCRITT. *Surveyor*, **111**, 503 (Aug. 9, 1952).

For the purposes of this article, the term "preliminary treatment" is taken to mean only the processes which precede primary sedimentation; namely, screening and grit removal.

Various available types of screens are considered, together with the factors influencing the choice of screen openings, of manual or mechanical cleaning, and of other points of design. The only method of screenings disposal discussed is disintegration, followed by either return to the raw sewage or treatment with the sludge. Comminutors combine the functions of the screen and disintegrator in one unit.

The discussion of grit removal consists of descriptions of various means of accomplishing the purpose, ranging from the simple detritus tank and the channels in which constant velocity is maintained by manual operation of penstocks, to carefully designed automatic equipment with provisions for continuous removal and washing of the accumulated grit.

M. C. RAND

BOOKS, REPORTS, AND PAMPHLETS

Third Annual Report (1951–52). Delaware Water Pollution Commission. 12 pp.

Fourth Annual Report. Ohio River Valley Water Sanitation Commission. 24 pp. (1952).

Guide for Federal Specifications WWP-401: Cast Iron Soil Pipe and Fittings. Cast Iron Soil Pipe Inst., Washington, D. C. 16 pp. (1952).

Chemistry and Bacteriology of Water for Treatment Plant Operators (Spanish). By J. R. HURTADO. Tipografia Vargas, Caracas, Venezuela. 131 pp. (1950).

Report on the Collection, Treatment and Disposal of the Sewage of San Diego County, California. San Diego County Sewerage Survey, San Diego, Calif. 515 pp. (1952).

A report prepared for the Survey by David H. Caldwell, Charles Gilman Hyde, and A. M. Rawn, acting as a Board of Engineers.

Book Reviews

Handbook of Chemistry. By N. A. Lange. Handbook Publishers, Inc., Sandusky, Ohio. Eighth Edition (1952). 1998 pp. Price, $7.00.

As with each previous edition, the eighth edition of this excellent reference work contains thorough revision of material previously presented, some new matter, and omission of some deemed somewhat less important than the new matter included. Even the mathematical tables have been cut to the essential minimum.

Although the title makes no mention of physical quantities, these are, of course, directly interwoven with the chemist's interest. The combination of both types of data in the one handbook is a happy one, making the book one of the type that will be used and not simply given shelf space. The detailed and excellently cross-referenced 26-page index is a masterpiece of "reader help" in finding the essential grain in the large mass of factual information stored between the fabrikoid covers.

Encyclopedia of Surface-Active Agents. By J. P. Sisley and P. J. Wood. Chemical Publ. Co., New York, N. Y. (1952). 540 pp. Price, $15.00.

Part 1 (198 pp.) deals with the general aspects of surface-active agents, their properties, applications and methods of manufacture. It also gives an efficient system of classification by which every variety of the modern surface-active agents can be identified by simple symbols.

Among the chemicals covered are wetting agents, detergents, penetrants, foaming compounds, emulsifiers, and dispersing agents. The book takes an inventory of all the sulfonated oils and modern detergents currently manufactured in all industrial countries, grouping them into main and subclasses according to chemical composition. It describes their many applications in a wide variety of industries.

Part 2 is a compilation of data on all major commercially available surface-active agents that appeared on the world market up to the publication of the book, arranged alphabetically by brand name. All available information on the various products is given.

This is a most valuable compendium, especially for those whose interests involve use and selection of surface-active agents. For the sewage treatment worker it simply codifies all the sources of possible detergent problems he may be called upon to solve.

Detergents—What They Are and What They Do. By Donald Price. Chemical Publ. Co., New York, N. Y. 159 pp. Price, $4.00 (1952).

By explaining the hows and whys of detergency in simple, nontechnical terms, this book brings detergents to the level of the average reader. Not only does it tell what detergents are and what they do, but it also discusses the various household and industrial applications of detergents in such a way as to make easier the choice of product to meet any particular need.

Man and Epidemics. By C.-E. A. Winslow. Princeton Univ. Press, Princeton, N. J. 246 pages. Price, $4.00 (1952).

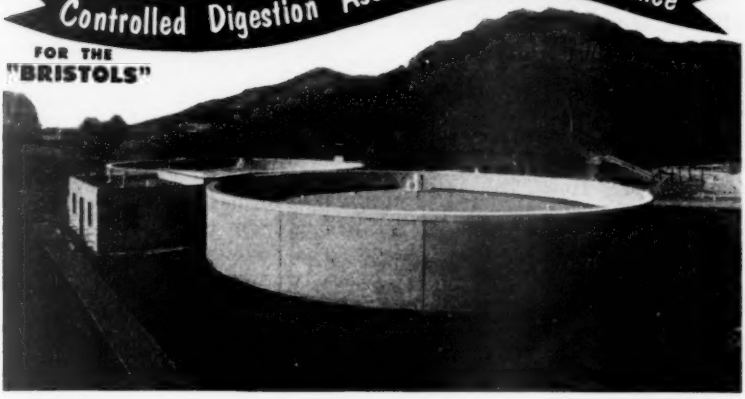
For the general reader this book presents a fascinating account of the modern engineering practices and scientific methods of control that make it possible for the average citizen to draw an ample flow of pure water from the faucet, to enjoy a milk supply of safe and sanitary quality, and to eat food without fear of infection. Although not designed for the expert, the book also provides a historical and philosophical background for the professional worker in the field of public health.

The chapter on "Disposal of Human Wastes," covering not only domestic sewage, but also ashes, rubbish, and garbage, gives a general picture of the problems involved and some of the means of solving them. H. P. Orland

P.F.T.

Controlled Digestion Assures Peak Performance

FOR THE "BRISTOLS"



NESTLED in the Appalachians are the "twin" cities of Bristol, Tennessee and Bristol, Virginia. Both cities are jointly served by a single sewage-treatment plant, of the high-rate trickling filter type P.F.T. Controlled Digestion is a highlight of the plant. Two P.F.T. 90' Floating Cover Digesters ably handle digestion of sewage sludge. Each is equipped with a P.F.T. Supernatant Selector piped to a P.F.T. Supernatant Gauge, Sight Glass and Sampler within the control room to provide systematic withdrawal of supernatant liquor. Two P.F.T. No. 750 Digester Heater and Heat Exchangers, gas and oil fired, with accessory group "D" controls, maintain the sludge in the digester at optimum temperature and also provide automatic building heating. P.F.T. Gas Safety Equipment safeguards every phase of sludge gas storage, transmission and utilization.

Wiedeman & Singleton, Atlanta, Ga., were the Consulting Engineers.

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Proceedings of Member Associations

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

The 26th Annual Meeting of the Ohio Sewage and Industrial Wastes Treatment Conference was held at the Commodore Perry Hotel, Toledo, Ohio, on May 21–23, 1952. Registered attendance was 209; in addition, 35 ladies enjoyed the special entertainment provided for them.

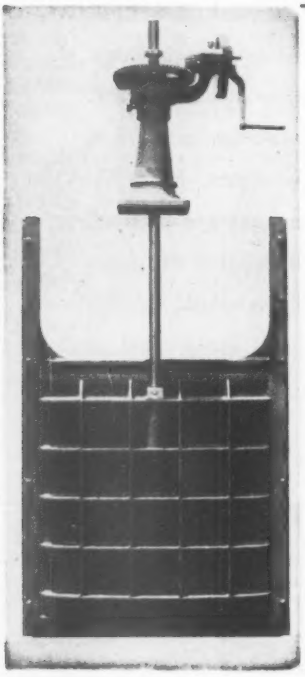
The morning of May 21 was devoted to a Manufacturers' Forum, which featured equipment for oil removal at the source, as well as at the sewage treatment plant.

In the afternoon, the conference was welcomed by L. E. Roulet, Mayor of Toledo. This was followed by "A Discussion of the New Ohio Water Pollution Control Law," by John D. Porterfield, Director of the Ohio Department of Health and Chairman of the Water Pollution Control Board, and G. A. Hall, Engineer-Secretary of the Board.

The Business Meeting occupied the remainder of the session.

The Thursday program was divided into two sessions running concurrently, one dealing with sewage treatment and the other with industrial waste problems. The entire morning in the sewage treatment section was devoted to discussion of plant problems. Subjects for discussion were selected from a questionnaire survey of all municipal

(*Continued on page 62a*)



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4. **UNUSUAL DURABILITY** that enables it to give long years of heavy-duty service.
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sewage treatment plants in Ohio, accomplished by the Sewage Plant Problems Committee of the Conference.

The afternoon session of the Sewage Treatment Section featured the following papers:

"Effects of Detergents," by W. R. Gowdy, Procter and Gamble, Cincinnati.

"Analytical Methods for Detergents," by G. R. Lewis, Chemical Engineer, E. I. Du Pont de Nemours, Old Hickory, Tenn.

"Determination of the Degree of Clogging in a Trickling Filter," by John R. Wolfs, Assistant Superintendent, Southerly sewage treatment plant, Cleveland.

"Experiences with Heat Exchangers at Cleveland, Akron, Columbus, and Dayton," with a discussion by L. E. Langdon, Pacific Flush Tank Co., Chicago.

The Thursday morning session of the Industrial Wastes Section was devoted to "Water Conservation to Reduce Pollution Load," by G. A. Howell, U. S. Steel Corporation, representing the steel industry; John Vogler, Calco Chemical Division, American Cyanamid Company, representing the chemical industry; and R. N. Simonsen, Standard Oil of Ohio, representing the oil refining industry.

The Thursday afternoon session of the Industrial Wastes Section featured the following:

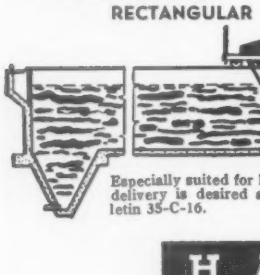
"The Reclaim Rubber Industry," by John R. Moore, Engineer, Firestone Tire and Rubber Co., Akron.

"The Waste Problem of the Synthetic Rubber Industry," by R. E. Rostenbach of the Synthetic Rubber Division of R. F. C.

"Metal Recovery by Ion Exchange," by T. J. Fadgen, Ternstedt Division, General Motors Corporation, Trenton, N. J.

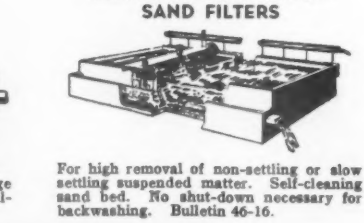
(*Continued on page 64a*)

CIRCULAR THICKENERS AND CLARIFIERS



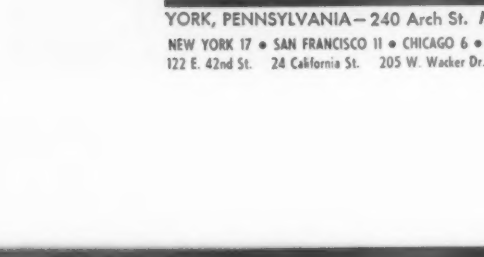
Small unit with steel tank

For removal of fine suspended solids from supply water, waste water and sewage. "Auto-Raise" mechanism prevents scraper breakage. Bulletin No. 31-D-16.



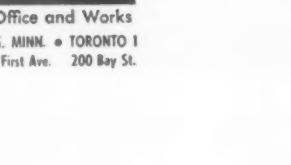
Large unit with concrete tank

RECTANGULAR CLARIFIERS



Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. Bulletin 35-C-16.

AUTOMATIC BACKWASH SAND FILTERS



For high removal of non-settling or slow settling suspended matter. Self-cleaning sand bed. No shut-down necessary for backwashing. Bulletin 46-16.

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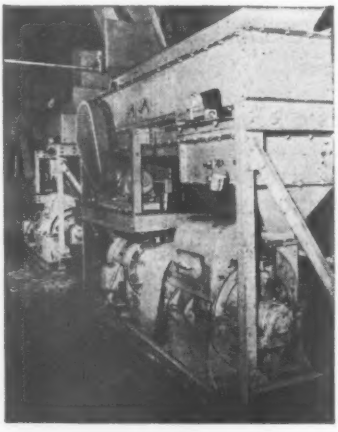

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The Friday morning session included the following presentations:

"Toledo's Improvement Program," by T. B. Henry, Consulting Engineer, Toledo.

"Removal of CO_2 from Sewage Gas," by James E. Frook, Chemist-Bacteriologist, Toledo sewage treatment plant.

"Report on Pollution Survey of the Maumee River," by Bruce M. McDill, Engineer in Charge, Water Pollution Control Unit, Ohio Department of Health, Columbus.

"Treatment and Re-Use of Water in Beet Sugar Manufacturing," by George S. Fleming, Superintendent, Buckeye Sugar Company, Ottawa, Ohio.

Friday afternoon was given over to an inspection trip of the Toledo municipal sewage treatment plant.

Entertainment features at the meeting, other than the formal program, included a Smoker on Wednesday evening sponsored by the Water and Sewage Works Manufacturers' Association, a Cocktail Party on Thursday evening sponsored by the same group, and the Annual Banquet on Thursday evening. The banquet program featured the formal presentation of the Arthur Sidney Bedell Award to A. H. Niles by President Boyce, and a very humorous talk on "The American Family," by Allen Saunders, author of several comic strips.

Officers elected for 1952–53 were:

Chairman: Donald G. Stevens, Cleveland.
1st Vice-Chairman: W. D. Sheets, Columbus.
2nd Vice-Chairman: Grant Pettit, Middletown.
Secretary-Treasurer: Ward E. Conrad, Columbus.

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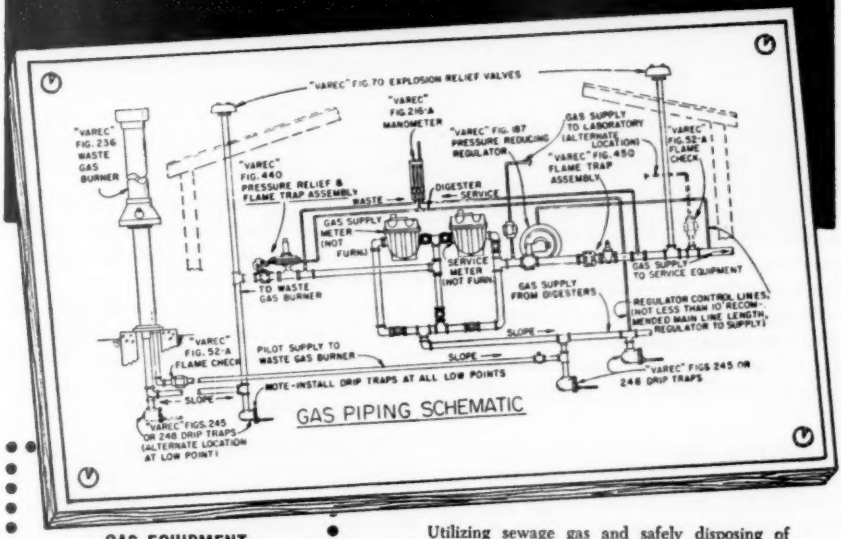
"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 52-A FLAME CHECK
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
GAS SUPPLY TO SERVICE EQUIPMENT
REGULATOR CONTROL LINES: (NOT LESS THAN 10 RECOMMENDED MAIN LINE LENGTH, REGULATOR TO SUPPLY)
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS
SLOPE
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

a. **PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 440

b. **FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

c. **FLAME CHECK**
"VAREC" Fig. No. 52A

d. **EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

e. **WASTE GAS BURNER**
"VAREC" Fig. No. 236

f. **DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

g. **MANOMETERS**
"VAREC" Fig. No. 216A

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Equipment and Supply Lines

Flow Meters—Recently revised, Instrumentation Data Sheet No. 10.3–4 describes operation of float-actuated, evenly divided flow meters especially applicable to Parshall flumes or weirs. Included are data on various system arrangements, and specifications of the instrument.—Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Electric and Electronic Controls—New 8-page selection guide (GEA-5781) contains quick-reference data and references on manual, magnetic, combination, and reversing motor starters; pushbutton stations; relays; limit switches; solenoids; photoelectric relays; electronic timers; electronic relays; pressure and vacuum switches; float switches; and other devices.—General Electric Co., Schenectady 5, N. Y.

Valves—"Equivalent Valves" manual, 170 pages loose-leaf, has been issued in a revised and enlarged edition. The manual compares valves of 18 leading manufacturers by material, type, pressure rating, and structural variations. The 1952 revision includes cast-iron and bronze valves for the first time.—Equivalent Valves Co., P. O. Box 816, Station H, Los Angeles 44, Calif.

Plastic Paint—New 8-page bulletin (No. 201) describes the characteristics, applications, and methods of use of "Corrosite" corrosion-resistant protective plastic paint.—The Corrosite Corp., Chrysler Building, 405 Lexington Ave., New York 17, N. Y.

Proportioning Pump—New catalog UP–52 gives full information on mechanical-drive U-type metering and proportioning pumps. This type pump can be used for feeding chlorine, ferric chloride, and other chemicals.—Hills-McCanna Co., 2448 W. Nelson St., Chicago 18, Ill.

Open-Channel Flow Meters—Bulletin F1606 describes a new line of Series 500 open-channel flow meters for mechanical or remote recording.—The Bristol Company, Waterbury 20, Conn.

Temperature Control Unit—Bulletin 4703 describes the Alnor Pyrotac, a new temperature control unit that automatically monitors up to 20 individual temperature points a minute.—Illinois Testing Laboratories, Inc., 420 N. LaSalle St., Chicago 10, Ill.

Anti-Rust Paints—New line of "Overust" chromate anti-rust paints for use on metals is available in six colors and can be applied to any kind of metal, directly over rusted surfaces without wire brushing or sandblasting, by either brushing or spraying.—Chem Industrial Co., 3784 Ridge Road, Brooklyn 9, Ohio.

Diesel Control System—Bulletin No. 4806-B describes necessary alarm and shutdown devices to safeguard the operation of stationary diesel engines.—The National Supply Co., Engine Division, Springfield, Ohio.

Excavator Operation—New 32-page booklet lists and explains rules of excavator and crane operation and maintenance.—Bucyrus-Erie Co., South Milwaukee, Wis.

Truck Winch—Bulletin No. 149T describes capacities and applications of Low-Mount winches for truck and tractor use.—Wayne Division, Gar Wood Industries, Inc., Wayne, Mich.

Filters—New 20-page brochure describes selection, applications, construction, and operation of various types of filters and auxiliary equipment. Of particular interest are the pages on sludge filters.—Process Equipment Division, General American Transportation Corp., 135 South LaSalle St., Chicago 90, Ill.

Circular Collectors

Types for every waste treatment problem

- DESIGNED FOR EFFICIENT LONG-TERM OPERATION
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TRACTOR DRIVE COLLECTOR

This pier-supported collector is designed for circular tanks. The rotating bridge acts as the lever arm rotating a sturdy center cage which carries the collector arms. Rotational force is provided by a two-wheeled, rubber tired tractor unit running on the rim (or effluent weir wall of the tank). Drive unit is simple, easily accessible, and not affected by snow or ice.

SUSPENDED COLLECTORS are used where a simple bridge can span the tank diameter. In this case, the complete motor and drive assembly, together with the drive tube and collector arms, are suspended from the bridge.

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This unit utilizes the principles of fluid mechanics, so highly developed in Walker sedimentation units. It removes all settleable solids and remarkably clarifies the flow. All parts are sturdily built... designed for the "tough" jobs.

WRITE FOR BULLETIN 10169

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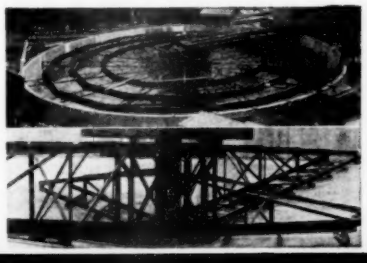
The Pier Drive Collector is recommended where it is undesirable to operate a Tractor Drive... where the access bridge must be stationary, or the corners of square tanks must be scraped. Center drive mechanisms, ranging from 1/2 to 10 horsepower, are built for long life and heavy duty service. Worms are carburized and ground steel and precision meshed with hardened bronze worm wheels. The balls run in hardened, ground, renewable ball races.



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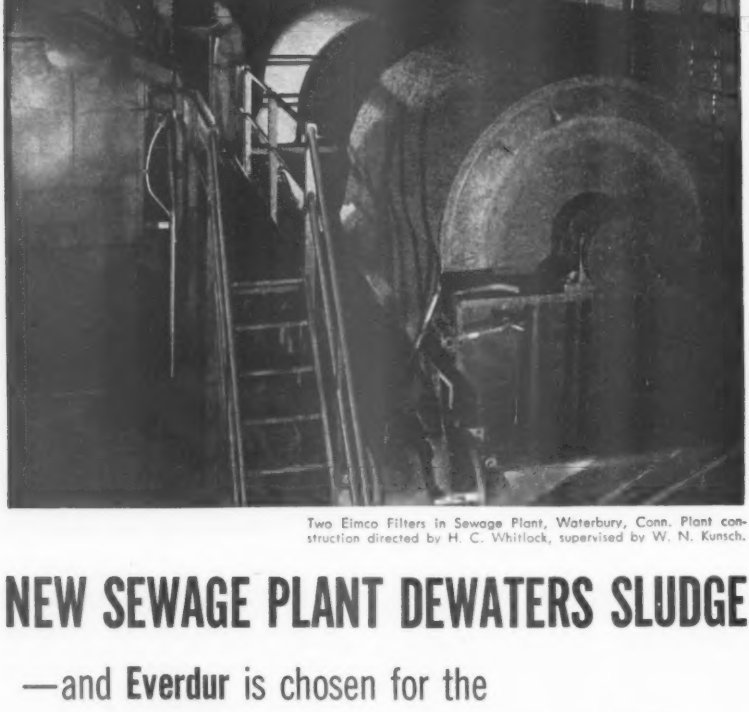

Two Eimco Filters in Sewage Plant, Waterbury, Conn. Plant construction directed by H. C. Whitlock, supervised by W. N. Kunsch.

NEW SEWAGE PLANT DEWATERS SLUDGE

—and **Everdur** is chosen for the Eimco Vacuum Filters that do the job

MALCOLM PIRNIE, consulting engineer of New York, designed the sewage plant for Waterbury, Conn. to treat domestic sewage mixed with industrial waste. Vacuum filtration and incineration were advised.

Eimco Corp. supplied two continuous rotary filters with swing agitators. Everdur* was chosen to resist the corrosive sludge effluent. All woven wire screens (5 x 5 mesh x .063" gage), division strips, bolts, nails and screws are Everdur.

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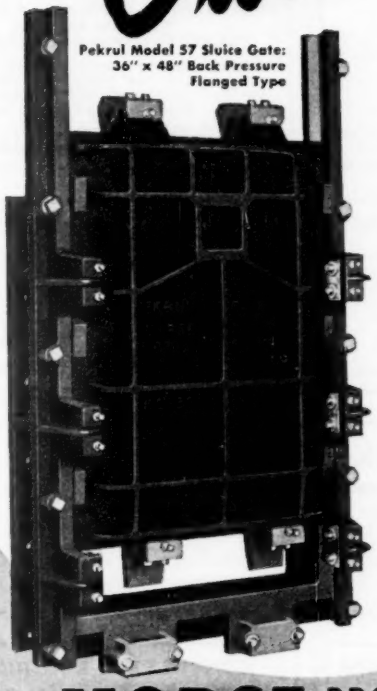

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(Continued through page 75a)

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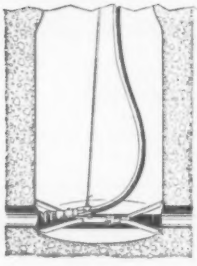

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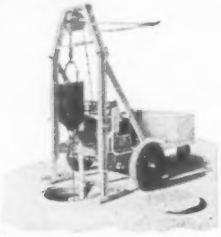

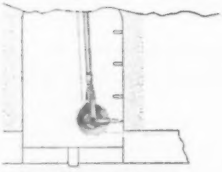

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